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SNETTISHAM HYDROELECTRIC PROJECT

CRATER LAKE - ALASKA

SECOND STAGE DEVELOPMENT

FINAL FOUNDATION REPORT

1992

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of Engineers

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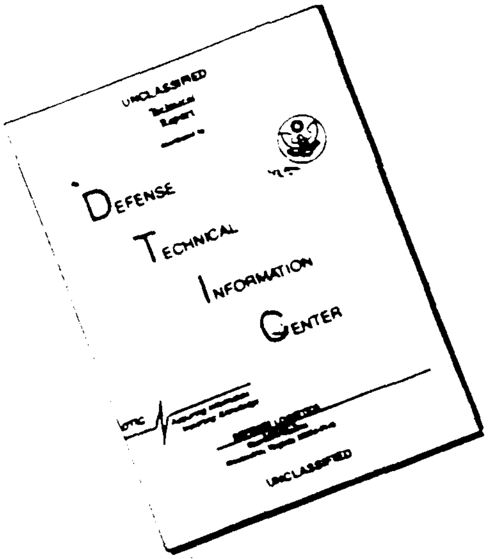

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13. ABSTRACT *(Maximum 200 words)*

The important geologic features and methods used to construct the Crater Lake stage of the Snettisham Hydroelectric project, built between 1985 and 1989, are discussed. The project added 31 megawatts of non-polluting, renewable electric power for Juneau, Alaska and the surrounding area. Features of the report include the power tunnel and access adits, penstock excavation, surge shaft, gate shaft and lake top. Construction aspects include the general geology, design features, construction methods, geologic conditions encountered, ground support requirements, grouting, instrumentation and tunnel filling. Foundation conditions for the Crater Lake status were excellent, permitting the power and penstock tunnel and shafts to be constructed essentially unlined. The basic rock type throughout the project is a high-quality, quartz diorite gneiss with randomly spaced, subparallel basalt dikes.

14. SUBJECT TERMS

Unlined rock tunnels; power tunnel; Penstocks; lake tap; surge shaft.

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Please note the following corrections in your copy of "Snettisham Hydroelectric Project, Crater Lake, Alaska, Second Stage Development, Final Foundation Report, 1992".

p. 4	¶ 1 line 2: date of LH&A report was 1986
p. 21	Reports in Appendix I should be referenced on p. 20 at the end of ¶ 2
p. 31	¶ 3 line 1: "intensive" should be "intrusive"
p. 41	¶ 1 line 6: Delete "52+75"
p. 48	¶ 3 line 1: "Dywidags" should be "Dywidag"
p. 58	¶ 3 last sentence: Repeated from above; delete
p. 69	¶ 3 line 3: should read ". . . weather permitted, the pilot and an L&A representative made . . ."
p. 70	Note at bottom of page should be referenced on p. 58, ¶ 2

Appx C, p. C-3: Caption for Photo 6 should be "Half-round drill casts resulting from smooth-wall blasting techniques in the Crater Lake penstock."

SNETTISHAM PROJECT
ALASKA

SECOND STAGE DEVELOPMENT

CRATER LAKE

FOUNDATION REPORT

1992

prepared for

U.S. Army Engineer District Alaska
Anchorage, Alaska

by

LACHEL & Associates, Inc.
Golden, Colorado

SNETTISHAM PROJECT FOUNDATION REPORT
CRATER LAKE STAGE

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I. INTRODUCTION

THE SNETTISHAM PROJECT

The Snettisham Hydroelectric Project was constructed by the Alaska District of the U.S. Army Corps of Engineers. The project, located 28 air miles southeast of Juneau (see Figure A-l), is operated by the U.S. Department of Energy, Alaska Power Administration, and primarily serves the purpose of supplying electric power to the growing cities of Juneau, Douglas, and Auke Bay, Alaska.

The project area has a marine climate with cool, wet summers and mild winters. Precipitation at the site averages about 130 inches per year, and snowfall depths range up to 10 ft at sea level.

The area is unpopulated except for approximately 15 year-round personnel who operate the Alaska Power Administration hydropower plant and the Alaska Department of Fish and Game fish hatchery. The hatchery uses the tailwater from the plant.

FIRST STAGE DEVELOPMENT

The first stage of the Snettisham Project included the development of the following facilities at Long Lake:

- o An 8,000-ft power tunnel
- o A 1,600-ft steel-lined penstock
- o An underground powerhouse
- o Two turbines and generators with a total installed capacity of 47,160 kW
- o 43.6 mi of transmission line to carry power to Juneau

This stage of the construction began in 1967, and the first power was delivered in 1972.

SECOND STAGE DEVELOPMENT

The second stage of the Snettisham Project was the development of Crater Lake.

Phase I

Phase I of this project included the construction of a series of tunnels from the existing powerhouse to the vicinity of Crater Lake. Contract DACW85-84-C-0016 for $5,538,000 was awarded on 28 September 1984 to South Coast, Inc., of Ketchikan, Alaska. The main features of the contract, as let, included the construction of 6,772 lin. ft of 10.5-ft-diameter, essentially unlined, power tunnel. Later contract modifications increased the total contract to $7,125,679 and provided for the following:

- o Expanding the penstock section to 14 ft high by 20 ft wide
- o Extending the penstock to the existing powerhouse
- o Excavating the 40-ft-long surge tank adit
- o Excavating the powerhouse machine shop and its adit.

Notice to proceed was issued on 18 October 1984, and Phase I of the work was completed on 28 October 1985.

Phase II

Phase II of the Crater Lake Stage was awarded to Pacific Ventures Inc., Bellevue, Washington, on 6 August 1986 for $22,272,079.50 and included construction of the following:

- o A 990-ft unlined surge shaft
- o A 251-ft concrete-lined gate shaft
- o An access adit to the gate shaft
- o A 690-ft extension of the power tunnel to the lake tap with three widened sections for rock traps
- o A lake tap excavation.

Also included in the contract was the installation of 896 ft of 6-ft-diameter steel penstock and a third generation unit, which increased the capacity by 31,000 kW.

The power tunnel was filled in April of 1989 and the Crater Lake Unit conducted test operations beginning in May. Shortly thereafter the unit was shut down for remedial repairs and started up on 20 October 1989 to supply firm power to the system. The location and details of the work done under Phases I and II are shown in Figures A-1 through A-16, and photos of specific features and activities during the construction of the Crater Lake Phase are shown in Appendix C.

THE FOUNDATION REPORT

This foundation report discusses the important geologic features and methods used to construct the Crater Lake Stage of the Snettisham Hydroelectric Project. The report was prepared in accordance with U.S. Army Corps of Engineers, ER1110-1801, Construction Foundation Reports, dated 15 December 1981, including Changes 1 and 2.

Detailed information on the preconstruction geologic explorations and investigations for the Crater Lake Stage of the Snettisham Project can be found in the following design memorandum: Crater Lake Phase, Design Memorandum No. 26 (Revised), 1984, U.S. Army Corps of Engineers, Alaska District. The designers of the underground excavations were Mr. James L. Williamson and Mr. Patrick J. Galbraith, U.S. Army District, Alaska, Geology Section.

This report was prepared by LACHEL HANSEN & Associates, Inc. (LH&A), now LACHEL & Associates, Inc. (L&A), Golden, Colorado. Included in the L&A scope of work were Title II construction management services, geologic mapping, inspection, quality control review, designation of ground support areas, instrumentation, and review of the contractor's construction methods.

A Foundation Report covering only the Crater Lake Phase I excavations was prepared by LH&A in 1968.[1] Data from that report, which is available from the Alaska District of the Corps of Engineers, have been included in this report.

For the Corps of Engineers, the Resident Engineer was Mr. James R. Volz, the Project Engineers were Mr. William Creger and Ms. Patricia Opheen, and the Quality Assurance Representative was Mr. Keith Boaz for Phase I and Mr. Terry Witherspoon for Phase II.

For LH&A, the geologic and tunnel engineering field work was provided by Mr. Dennis J. Lachel and Mr. John C. Bowman for Phase I, and by Mr. Dennis J. Lachel and Mr. Harry F. Steeves for Phase II. Editorial assistance was provided by Mrs. Susan V. Heisler, Ms. Mary Appleby, and Ms. Sandra Myers.

1 LACHEL, HANSEN & Associates, Inc., 1986, Foundation Report, Snettisham Project, Alaska, Crater Lake, Phase I: Power Tunnel, Sta. 68+50 to 13+50, Access Adit, Penstock, Machine Shop: Prepared for U.S. Army Engineer District, Alaska; Anchorage, Alaska.

II. PROJECT SUMMARY

POWER TUNNEL AND ACCESS ADITS

The power tunnel for the Crater Lake Stage of the project extends from the lake tap, at Sta. 6+60, to the beginning of the penstock tunnel, at Sta. 68+75. From the gate shaft, it is at a constant grade of 12.44 percent. The power tunnel plan, profile and cross section are shown in Figures A-2 and A-3. The tunnel cross section is typical along its length, except for the widened areas used for muck bays during construction, niches in the side wall to house transformers, and modified sections (described under the heading "Lake Tap") to provide rock traps for the lake tap.

A second tunnel with the same cross section as the power tunnel provides access from the surface to the service room at the top of the gate shaft. This service room access tunnel is 880 ft in length from the portal entrance at Sta. 8+80 to the centerline of the service room at Sta. 0+00. It is constructed at a constant grade of 0.56 percent, starting at the portal and ending at elevation 1,040 at the service room. Figure A-2 shows this feature. Muck from the service room and its access tunnel was deposited at the portal to construct a helicopter landing pad and staging area.

Access adits to the penstock tunnel, the surge shaft, and the machine shop were completed under the Phase I contract.

PENSTOCK EXCAVATION

The penstock excavation begins at Sta. 68+75, with a transition area beginning at Sta. 67+43 where it joins the power tunnel at invert elevation 127.08. It continues as an unlined tunnel for 898 ft to Sta. 77+48, where it intercepts the first stage (Long Lake) development penstock excavation at invert elevation 02.0, immediately upslope from the valve room wall. The penstock tunnel bears S 59° 36'36" E at its junction with the power tunnel at Sta. 67+43. It maintains this bearing to Sta. 76+97.25, where it bends

on a 100-ft radius to align with the existing penstock excavation to the valve room at Sta. 77+48.64. From this point to the valve room the penstock bears S 30° 09'11" E. The grade of the penstock is 12.437 percent from Sta. 68+43 to Sta. 77+48.64, where it flattens to 0.0 percent grade. The penstock is shown on Figure A-2.

SURGE SHAFT

The surge shaft (see Figure A-2), as initially designed, was to be a vertically excavated 10-ft-diameter shaft from an adit off of the power tunnel at Sta. 66+32. When construction survey control was being established at the shaft, the daylight point was found to be in deep talus with boulders up to 15 ft in diamater. To avoid excavating the talus or removing it, the shaft was inclined 4.7° from vertical to a surface intercept near the location of drill hole DH-99. At the same time, the excavated cross section was changed to a 9-ft square to accommodate the contractor's shaft-excavation equipment. The unlined, square, surge shaft has a rock trap at its base, excavated to elevation 138.38, and extends from power tunnel invert elevation 143.38 to the top of a vented concrete cap at elevation 1090.0.

GATE SHAFT

The gate shaft, located at Sta. 14+00 of the power tunnel, is a 10-ft by 12-ft rectangular shaft that flares to 20-ft by 16-ft at its intersection. The power tunnel gate enlargement is at the lower end of the shaft, and the invert of the bottom of the gate is at elevation 789.0. The 10- and 20-ft dimensions are parallel to the power tunnel centerline. The gate shaft is flared at the top to allow a protective grating in the floor of the service room. This floor is at elevation 1040.0. Figure A-2 shows the gate shaft.

LAKE TAP

The intersection of the power tunnel and Crater Lake was made using what is commonly called the Norwegian Lake Tap Method. The technique involves excavating

the power tunnel to within a few feet of the bottom of the lake, in this case under 210 ft of water, and blasting a hole into the bottom of the lake with a single excavation round. The designed lake tap included three rock traps: primary, secondary, and tertiary. Because of rock conditions, the alignment, size, and location of the secondary rock trap had to be changed. The plan of the lake tap is shown in Figure A-4. The changes in configuration are described in Section IV.

III. GENERAL GEOLOGY

REGIONAL GEOLOGY

Southeastern Alaska is primarily an archipelago of several hundred islands of various sizes abutting a mountainous mainland. The islands are the tops of a rugged, submerged coastline, the result of a geologically recent rise in the sea level. The major inlets and passages are, in fact, drowned river valleys. These fjords were carved and scoured by large glaciers moving westward out of the mountains to the east. The glaciers were thousands of feet thick, as attested to by the fact that most of the mountains less than 2,000 ft high above the present sea level have been overridden and their tops rounded off. The valleys are typically U-shaped, and active glaciers are found at the heads of many rivers. Numerous waterfalls plunge into the valleys from the surrounding peaks, and the valley bottoms are filled with moraines, braided streams, and alluvial deposits composed of glacial detritus.

The Snettisham Project site lies near the western edge of a large, probably Cretaceous Age, complex of igneous/metamorphic rock called the Coast Range Batholith. This long, narrow, mass of rock generally parallels the southeastern Alaska coast. Soil cover on the slopes is relatively thin, and geologic weaknesses in the bedrock, such as soft or fractured rock, have been plucked and gouged by glacial action. The orientation and alignment of major topographic features of the region are usually controlled by structural geologic features such as fault zones, intrusions or joint sets.

Faulting in the region is common, although no evidence of recent faulting (since the last glaciation) has been observed in the immediate vicinity of the project. At least five great earthquakes with estimated Richter magnitudes of 7.9 or higher have occurred within 300 miles of the Snettisham Project (see Table I).

TABLE I Great Earthquakes in the Snettisham Project Area

Date	Epicenter Coordinates	Magnitude	Depth (km)	Location
1899 Sep 04	60N 142W	8.5	unknown	Near Cape Yakataga
1899 Sep 10	60N 140W	8.4	unknown	Yakutat Bay
1900 Oct 09	60N 142W	8.1	unknown	Near Cape Yakataga
1949 Aug 22	53N 133W	8.1	25	Queen Charlotte Islands
1958 Jul 10	58.6N 173.1W	7.9	unknown	Lituya Bay

SITE GEOLOGY

The Snettisham Project is located at the head of the Snettisham fjord, near the mouth of the Speel River. It is an area of steep-sided mountains rising to heights of 3,000 ft above the valley floor. The valley floor and lower mountain slopes are covered with very large coniferous trees (mostly Sitka spruce) and heavy underbrush. The tops of the mountains are generally bare rock, which has been scoured and rounded by geologically recent ice sheets.

Overburden in the project area consists of thick deposits of glacial outwash in the valley bottoms, with superimposed meandering streams, sand and gravel moraines, and recent alluvial deposits. During the summer, the streams with glaciers at their headwaters are heavily silt-laden. Some varved clays are present near Second Lake (see Figure A-1), representing seasonal deposits in a glacial lake. The overburden becomes thin as one proceeds up the slopes. In the immediate project area, the tree line is about 1,000 ft above sea level.

The subsurface site geology, as it relates to project features, is described in the following sections and is shown on geologic profiles on Figure A-5 (power tunnel), Figure A-6 (penstock), and Figure A-7 (lake tap area and gate structure).

Completed Explorations

Subsurface explorations, consisting of 40 NX and NQ core holes totaling 8,175.4 lin. ft, were designed to investigate specific geologic features. The locations of all completed exploratory core borings in the vicinity of Crater Lake, as well as the log records of the drill holes are presented in Appendix F.

Geologic Tunnel Mapping

All of the underground excavations completed during this project (the Crater Lake Phase) were mapped for geology using the full-periphery geologic mapping method. The results of this mapping are presented in Appendix B.

Bedrock Lithology

The bedrock encountered in the Crater Lake tunnels is typical of the bedrock throughout the Snettisham Project. The rock is predominantly quartz diorite gneiss. Lesser amounts of quartz diorite and biotite-hornblende schist are encountered in the rock mass. Cutting the rock mass are dark gray-green basalt dikes and, less commonly, granite dikes. Small veins of quartz up to 4 in. thick are seen occasionally. Mylonitized zones are present as alteration products in some of the shear zones.

The quartz diorite gneiss commonly consists of alternating bands of dark and light, subparallel layers of four minerals: quartz, feldspar, biotite mica, and hornblende. The light-colored layers contain primarily equidimensional quartz and feldspar with minor amounts of dark minerals. The darker-colored layers are composed of small plates of biotite mica and tabular to prismatic hornblende, as well as some quartz and feldspar

minerals. Larger mica sheets, i.e., greater than 1-inch-diameter, have not been encountered. Pyrite crystals are somewhat common throughout the rock mass, and chloritization has occurred near some shears. Petrographic studies conducted previously by the Corps of Engineers show that a representative quartz diorite sample contains approximately 18 percent dark minerals, of which 13 percent is biotite and 5 percent is hornblende. Light-colored minerals make up 79 percent of the sample, of which 60 percent is plagioclase feldspar, 15 percent is quartz, and 4 percent is orthoclase feldspar. The remaining 3 percent of the sample is miscellaneous accessory minerals. The results of laboratory tests on Crater Lake rock core are shown in Appendix H.

Several zones, up to 50 ft thick, with a predominance of biotite and hornblende minerals were encountered in the tunnels. The zones were softer than the quartz diorite and, consequently, drilling was faster there than in the quartz diorite. Stress-relief slabbing, discussed in Section VII of this report, usually takes place in these biotite-rich zones, probably because of their inherently lower tensile/shear strength.

The gray-green basalt dikes range in thickness from a few inches to about 12 ft. Most are quite massive, but a few are blocky with randomly oriented fractures, which produce cube-shaped blocks down to about 3 in. on a side. Invariably, it appears that the basalt was intruded along previously existing discontinuities, both shears and joints, in the rock mass. Because the vast majority of the discontinuities in the tunnel are part of the same set, N 25° to 35° E, the strikes of most of the basalt dikes are approximately parallel.

Distinct zones of biotite-hornblende schist were not encountered in the Crater Lake tunnels.

Discontinuities

The entire rock mass is cut by numerous joints, dikes, faults and shear zones. The most striking aspect of the discontinuity pattern at Snettisham is the overwhelming pervasiveness of one fracture set. This set strikes N 25° to 35° E and dips from 65° to vertical with a southeast direction dominant. A simple counting of joints in several areas of the Crater Lake power tunnel indicated that this fracture set outnumbers all others combined by at least 20 to 1.

The Long Lake power tunnel was driven approximately parallel to this alignment. In the Crater Lake Stage this fracture set intercepted the main part of the power tunnel at a 15° to 25° angle to the alignment. This had two effects, one positive and one negative. The positive effect was that a discontinuity was typically first seen as a minor feature in the lower right hand corner of the advancing face. The miners were forewarned of conditions while the feature was down low and of little consequence. By the time the tunnel advanced to the point that the condition was in the crown, the miners knew what the condition was, whether it had water associated with it, and what type of ground support would be most appropriate. The negative effect was that the angle of interception produced a well-developed "sawtooth" roughness pattern in the side wall of the power tunnel. This roughness causes undesirable hydraulic conditions in a predominantly unlined tunnel.

Most of the discontinuities encountered in the tunnel are joints, which are typically planar, relatively smooth, and tight. Even where a well-developed joint is seen in the tunnel wall, it is usually impossible to insert a knife blade into the continuation of the plane. The majority of the joints are probably more accurately characterized as "incipient," because it is almost impossible to find them in the rock mass. A few of the joints have a chlorite coating and an even smaller number have slickensides, both features indicating that small movements have occurred. Most of these joints are probably the result of tectonic activity.

A joint system that has been observed in the Snettisham area, but which was encountered only in the Lake Tap area of the Crater Lake power tunnel, is the unloading or stress-relief joint. This type of discontinuity, common near the rock surface, occurs in response to the relatively rapid removal of heavy loads imposed on the rock surface by glaciers. The rock rebounds from the load elastically, which produces tensile stresses that fracture the rock. These joints have their highest frequency close to and parallel to the rock surface, and become less frequent with depth, usually disappearing within tens of feet below the surface.

Shears are the second most common discontinuity in the Snettisham Project rock mass. Their frequency is minor compared to that of the joints. In the Crater Lake power tunnel, for example, there were more than 50 shears of varying width and condition, but literally thousands of joints; however, they are an important feature.

The shears range from a single fracture with a smear of clay gouge and alteration to major shears with a width of alteration and gouge approaching 10 ft thick. Some of the shears contain broken and fractured rock, while others have a thin clay gouge with only a small alteration zone, less than a few inches wide. One of the most interesting features of the shears is how quickly the transition occurs from hard, intact, unaltered rock to the fractured rock and back again to the intact rock. In one instance, there is a 1-in.-thick clay gouge zone and yet only 4 in. away the rock appears to be totally unaffected.

Two major shear zones consisting of several parallel and subparallel shears were encountered in the Crater Lake tunnels. The first, the Rock Trap Shear Zone, is located just up tunnel from the penstock/power tunnel intersection at Sta. 68+50. The zone consists of five shears, with varying degrees of fracturing and alteration, which extend along the tunnel about 120 ft. Between the individual shears is relatively good quality rock. Complete descriptions of shears encountered in each tunnel are presented in the individual discussions of those tunnels.

The second major shear zone, the Hilltop-Cliffside Shear Zone, was encountered upstream of the gate shaft between the tertiary and secondary rock traps. It consists of a mylonitized gouge core 6 to more than 18 inches wide, with an adjacent, highly fractured, pegmatitic zone up to 10 ft wide. Parallel and subparallel shears continue extensively on both sides of the highly fractured zone, and a similar fractured, pegmatitic zone exists upstream in the left wall where the secondary rock trap was to be located. The design and location of this rock trap were changed because of potential construction and stability problems with this zone.

In-Situ Stress

In-situ stresses within a rock mass can result from many factors. The obvious one is the weight of the overlying rock. In some cases, however, the stresses are greater than that of the rock cover. The higher-than-normal stresses can be attributed to the following factors:

- Greater rock cover that has been eroded away
- Stresses imposed by tectonic forces
- Igneous injection
- Glacial loading.

It is likely that all of these factors influenced the in-situ stress field in the Snettisham area. However, glaciation probably had the most significant recent influence. Up to 5,000 ft of ice probably covered the area as recently as 5,000 years ago. The weight of this ice caused stresses which remain in the rock mass.

The most obvious effect of the high stresses is the existence of stress-relief joints and fracture patterns in the near-surface rock exposures. These joints are typically parallel to the rock surface and decrease in number with depth. At Long Lake, there were usually 2 or 3 joints per ft at the surface, decreasing to 1 joint per 5 ft at depths of about 20 ft.

During the driving of the Crater Lake tunnels, evidence of stress release was noted. On a number of occasions, the miners reported hearing rock "pops," particularly during the mucking cycle while they were waiting for the load-haul-dump (LHD) scooptrams to come back up the tunnel. Actual observances of stress release were rare, especially in the competent rock at Snettisham and under the maximum rock cover (about 1,000 ft). However, several occurrences noted in the tunnel appear to be stress-related.

In certain sections of the tunnel where the foliation or existing joint patterns were subparallel to the tunnel, loosening of the rock was apparently occurring, particularly in the nearly straight side walls of the tunnel. Between approximately Sta. 53+00 and Sta. 57+00, where the tunnel was under about 850 ft of cover and was approaching the Tlingit Shear Zone, the miners performed an inordinate amount of scaling on the side walls. As originally driven, the side walls were straight; however, stress-relief joints developed several tens of feet behind the advancing face, loosening the side wall rock. The loose rock was scaled off, and the result was a more stable, circular-shape tunnel.

Undoubtedly the most dramatic effect of stress release was seen on the left wall of the tunnel at Sta. 66+75. At this location, which is very close to the point where the vertical rock cover is at its maximum of 990 ft, numerous new stress-relief fractures were produced as the ground was reaching a more stable configuration. At a contact between a highly competent gneiss and a large biotite-rich pod, new tension fractures formed parallel to the tunnel walls and up to 12 in. long. Although most of the slabbing occurred shortly after excavation, new, smaller slabs continued to show up for several months. The pieces that have broken off show tension fracture characteristics: convex shapes, sharp edges, and lack of shearing through the mineral grains. As a result of the stress-relief fracturing, the left side wall of the tunnel extends up to 2 ft beyond the design line. The biotite-rich pod dips to the north and is not exposed on the right wall.

IV. DESIGN FEATURES

ORIGINAL DESIGN FEATURES

The original design incorporated construction of a power tunnel and appurtenances for a third generator in the existing powerhouse at Snettisham. In the first (Long Lake) stage, the powerhouse was constructed with a third, unused, bay for this subsequent installation.

In the projects second stage, the Phase I contract rock excavation work provided about 9,000 ft of power tunnel penstock, and access adits. In Phase II, the power tunnel was excavated to an area where Crater Lake was tapped to provide the water for the third turbine. Along with power tunnel construction, the excavation work required three rock traps downstream of the lake tap, a gate shaft and gate shaft service room (with separate adit), and a surge tank shaft upstream of the powerhouse. Incidental work also included widening an excavation for the tunnel plug, excavating a new machine shop cavern, and driving an adit from the new machine shop area to the original powerhouse machine shop area. Figures A-1 and A-2 show the location of these features.

CHANGES AND/OR CONTRACT MODIFICATIONS

Certain features in the contract documents were subject to conditions that required additional attention, or in some cases, modification of the contract. These included the following:

- Lake tap orientation
- Primary and secondary rock traps
- Tunnel section through the Hilltop-Cliffside Shear Zone
- Surge tank daylight location and collar
- Lining upstream of tunnel plug

- o Portal at access adit to service room
- o Final plug between old and new machine shop.

Lake Tap and Rock Traps

Lake tap modifications became necessary because of unfavorable rock conditions encountered at the location of the secondary rock trap, and because of the configuration of the lake bottom at the point of the tap. The rock encountered in the left wall at the proposed secondary rock trap was composed of highly fractured pegmatite similar to that encountered at the Hilltop-Cliffside Shear Zone (see discussion below). For this reason, the secondary rock trap was moved upstream and deepened. See Figure A-8 for details of the as-built rock trap.

The orientation of the tunnel at the lake tap was also modified following an investigation of the lake bottom configuration by probe holes. See Appendix E for the lake tap reports.

Hilltop-Cliffside Shear Zone

Based on aerial photography, surface geologic mapping, and exploratory drilling, the existence of the Hilltop-Cliffside Shear Zone was established prior to letting the Crater Lake Main (Phase II) Contract. The Alaska District geologists accurately described the condition of the shear and provided for exploratory drilling ahead of the advancing tunnel to locate and appraise the possible tunneling conditions.

Therefore, prior to beginning tunnel excavation upstream of the gate shaft, a horizontal, cored, pilot hole was cored, starting at Sta. 13+50, in an attempt to intercept the predicted Hilltop-Cliffside Shear Zone. The end of the pilot hole and the projected strike of the encountered shear zone were in close proximity; however, the pilot hole did not intercept the shear, even though it was carried well beyond the area where it was projected to intersect the power tunnel.

During tunnel excavation, the contractor encountered the shear zone at approximately Sta. 10+09. The shear zone was not as extensive as predicted and did not result in dangerous excavation conditions. However, the initial fractured rock condition, along with the contractor's inability to provide the wet-mix shotcrete called for in the contract documents, resulted in construction delays and the use of steel set supports, a much more expensive alternative rock support.

As the tunnel intersected the fractured rock of the shear, rock bolts were placed in the right wall, but did not totally contain the material sloughing from the shear zone. This, combined with the contractor's lack of satisfactory shotcrete to supplement the rock bolts, resulted in the continued use of steel sets to support the fractured rock and allow the excavation to progress. Steel sets were placed on 4-ft centers from Sta. 10+25 to Sta. 9+81 before the contractor was able to place shotcrete.

Shotcrete was finally placed from Sta. 9+81 to Sta. 9+58 using the contractor's initially proposed shotcrete mix. Although the shotcrete worked well in supporting the most broken and sheared portion of the shear zone, considerable difficulty was experienced in placement and in obtaining design compressive strength. The contractor's shotcrete operation was slow and apparently inefficient, and the early compressive strength break tests were below specifications. The low strengths were probably due to a lack of proper control of the accelerator. Because of the decision to provide this area with a concrete tunnel lining as a permanent support, the contractor proposed placing chain-link fabric and rock bolts in lieu of rock bolts and shotcrete as a temporary measure until excavation was completed through the shear zone. Rock bolts and fabric were used from Sta. 9+58 to Sta. 9+36.

The successful use of shotcrete in the worst section of the shear zone indicates that rock bolts with shotcrete (or mesh) would have been totally adequate support for the fractured rock area of the shear zone. Of the steel sets placed, only those in the 15-ft-long area of the right wall where a large rock block sloughed were taking load.

If the contractor had been able to provide satisfactory shotcrete when the shear zone was encountered, the use of sets probably would not have been required. It is our opinion that the sloughing of the large block from the right wall would have been contained by shotcrete placed over the rock bolts installed.

In an attempt to determine the rate of closure of the tunnel periphery, convergence points instrumentation was placed adjacent to installed sets during the Christmas, 1986 break when the contractor was not working. The results of this instrument testing are summarized in Section IX of this report. The conclusion from the testing was that rock closure was not a problem and steel sets were unnecessary.

Surge Tank and Collar

When the contractor verified the location of the top of the surge shaft (i.e., where the shaft would "daylight") in its original vertical orientation, the top was in a talus area consisting of large boulders. Consequently, the Corps decided to relocate the top of the shaft without relocating the bottom, making the shaft 4.7° from vertical. Driving the raise out of plumb increased the difficulty of excavation, although the rock itself was excellent.

After relocation, the top of the surge shaft was cleared of overburden and several rounds of explosives were fired before starting to raise the excavation from below. The last round fired at the top was left unmucked, which lead to a difficult and dangerous holing- through (daylighting) process later. The raise excavation from the power tunnel was stopped approximately 11 ft from the surface, the area of the last, unmucked, surface round. The removal of the final 11 ft from the top of the gate shaft required a great deal of hand mucking and many more explosive rounds fired than would have been necessary with a cleaned surface.

The damage caused by extensive blasting using multiple rounds, combined with the vertical rock jointing at the surface, prevented the use of a shoulder collar at the top

of the surge shaft for the surge cover to rest upon as originally designed. Additional horizontal dowels were placed on part of the periphery to support this collar.

Lining Upstream of Tunnel Plug

As recommended in the Foundation Report prepared for Crater Lake, Phase I, and similarly recommended by the Corps' lake tap consultant, the concrete tunnel lining was extended upstream of the penstock/tunnel plug area. In addition, the original design requirement for three consolidation grout rings was increased to seven. The location of the seven rings and the extension of the concrete lining are described in Section VIII.

The concern in this area was the blocky, fractured, rock associated with the Rock Trap Shear Zone, just upstream of the originally designed end of the concrete lining in the penstock/tunnel plug area. Because of the relatively shallow rock cover at this location, the fractures could have conducted high-pressure water to some of the fractured zones downstream and, perhaps, to the surface as leakage.

The procedure for and results of the consolidation grouting in this area are described in Section VIII. Post-construction investigations of this area were conducted by two consultants, Mr. C. O. Brawner and Mr. L. L. Oriard. Their reports are included in Appendix I.

Portal at Access Adit to Service Room

The orientation of the surface rock joints at the portal of the access adit to the service room required some modifications to the slope of the right wall (looking into the adit). The strike of the parallel joint system was approximately 15° to 20° from the centerline of the access adit. The dip was approximately 20° to 25° from horizontal.

This orientation was not at great variance from the design orientation of the portal side slope; however, the rock showed an excessive tendency to weather between the sets of vertical joints.

There was concern that the weathering had the potential to create debris which could fill the drainage swale at the periphery of the helicopter pad and divert water, eventually eroding the pad. To avoid this possibility, an additional 3-ft slab (to the next predominant rock joint) was blasted off, leaving a wider drainage swale with more storage capacity for debris.

Machine Shop Plug

Removal of the 6-ft-thick plug between the newly excavated machine shop and the existing underground power house was a concern because the blasting was close to the operating turbines and switchgear. As a mitigating measure, the whole periphery of the plug was line drilled and reamed to define the peripheral break line and minimize shock wave transmission.

The interior portion of the plug was drilled out and loaded with several blast-initiating delays to minimize the peak particle velocity of the delay segments. The shock waves were read by a seismograph just to the rear of the nearest turbine, and the peak particle velocity recorded was well below the maximum velocity specified of 1 in./sec. The operating Long Lake turbines were never shut down by construction of the Crater Lake Stage of the Snettisham Project. Figure A-9 shows the detailed pre-blast pattern for the plug proposed by the contractor.

V. CONSTRUCTION METHODS

PHASE I

South Coast, Inc., the contractor for construction of the access adit, penstock, and power tunnel up to Sta. 13+50 (Crater Lake Phase I), chose to drive their tunnels by the drill-and-shoot method. The contractor worked two, 10-hr shifts per day with an average of five miners in the tunnel per shift. Typically the personnel consisted of one shifter, two drillers, and two mucker operators who also erected tunnel utilities. Phase I was completed as a non-union project. A total of 314 days was required to drive the 6,772 ft of tunnel. The average advance rate was approximately 33 ft per work day, and the maximum advance rate for one 24-hr period was 48 ft (see Figure A-10). The machine shop addition to the powerhouse, the adit to the surge tank, and the lower portion of the penstock below the expanded section were excavated after the main tunnel drive.

Air-track and jack-leg drills were used to develop the portal area of the access adit, as well as the first few rounds in the adit. This reach was used for the blast test rounds required in the specifications. Shortly thereafter, a new Tamrock, two-drill, hydraulic jumbo was delivered to the site. Using 12-ft drill steel and 1-7/8 inch-diameter button bits for the blast holes, the jumbo drilled 10-ft tunnel rounds with an average pull length of 9 ft. The drills generated 100 hp with a 460-volt system, used water for total dust control at the heading, and required two miner/operators. In the larger diameter penstock, a third miner was required to help align the holes at the face. The drilling rates were quite fast, ranging from about 4 ft/min in the harder basalt dikes to about 6 ft/min in the softer biotite-mica rich zones. In the predominant quartz diorite rock the average drill bit life for the carbide insert button bits was approximately 400 ft per bit.

The tunnel was originally designed as a modified horseshoe, 10 ft 6 inches in diameter. However, before the start of construction, South Coast, Inc. requested, and received, permission to drive an 11-ft 6-inch straight-leg tunnel as a construction expedient.

Upstream of approximately Sta. 55+00, an 11-ft 6-inch modified horseshoe shape was used at the contractors request to reduce the total volume of rock excavated.

Mucking out the blasted rock in the tunnels was handled by two contractor-leased and one contractor-owned Wagner load-haul-dump (LHD) scooptrams. During the course of the job, two ST-8 (8-yd^3 capacity) and one ST-5 (5.5-yd^3 capacity) LHDs were used. The ST-8 mucked out the access adit, the ST-5 and ST-8 mucked out the penstock, and the two ST-8s mucked out the power tunnel. One of the LHDs was primarily for back-up, in case a mucker broke down. Compressors for the tunnel work included a 600-cfs Ingersoll-Rand to provide air for the equipment in the tunnel.

Ventilation for the tunnel was provided through new, 36-inch steel vent line manufactured for the project. By completion of the project, six reversible fans with a total capacity of 450 hp had been installed, three at the portal and one approximately every 1,800 ft up the tunnel. The total volume of air measured and maintained near the face was never allowed to drop below 43,200 cfm. A supplemental venturi fan was used to move the air from behind the vent line discharge and around the jumbo to the face.

Supplemental holes in the rock for rock bolts and utility support hangers were drilled with a pneumatic jack-leg drill.

Portal equipment included one Cat 988 front-end loader (6-yd^3 capacity) for loading the two dump trucks (15-yd^3 capacity) which hauled the tunnel muck for the road construction and to the muck disposal area at Crater Cove. Grading and dressing of the road was handled by a Caterpiller D-6, a Caterpiller D-8, and a road patrol/grader. One man loaded the muck from the muck pile at the portal and hauled the material to the disposal area. Hauling to the disposal area was done only on the day shift.

PHASE II

In keeping with the Phase I contract, the Phase II, (Main Contract) contractor, Pacific Ventures Inc., chose to use the drill-and-shoot method in lieu of a mechanical excavation system for excavating the remaining power tunnel, rock traps, service room, and lake tap. The basic work day was two 10-hour shifts, and tunneling crews consisted of four miners, one being the shifter. The time of execution for the different parts of the Phase II are included in the tunnel construction progress reports on file with the Corps of Engineers.

The basic tunnel production work was by a two-boom, hydraulic, drill jumbo with air-track and jack-leg equipment used in support. The second contractor also asked to drive a straight-leg tunnel on reaching the tertiary rock trap. He maintained that cross section for the remainder of the power tunnel, as well as for the access adit to the service room over the gate shaft.

Because the service room and access adit were located at elevation 1040 in an area without roads or trails, the contractor chartered a skycrane helicopter to transport tunneling equipment up to the site. Helicopters were also used to take equipment and personnel to the surge shaft collar area. All concrete placement in both areas was also done by helicopter.

The Phase I ventilation equipment left by the first contractor was used in Phase II. It was extended upstream in the same manner as for Phase I.

Mucking methods for the Phase II were modified from Phase I. After first trying to muck the heading from Sta. 13+50 to the lake tap using two ST-8s and one ST-3-1/2 Wagner LHD scooptrams, the contractor determined that the haul down tunnel was arduous for the scooptrams as they were frequently down for maintenance. The contractor then acquired three mine trucks to haul muck from the muck bays to disposal areas.

The raises for the surge and gate shafts were excavated using an Alimak climber from the bottom of the shaft upward. The surge shaft was done first, followed by the gate shaft. This work was subcontracted to the J. S. Redpath Co. of Canada. The contractor used jack-leg air drills off the platform for drilling blast holes. The mucking for the raise operation was done using the tunnel mucking equipment.

Support Facilities

South Coast, Inc. erected a 40-ft by 40-ft prefabricated metal building near the portal to use as a shop for equipment repair. Both contractors used this facility. A fulltime mechanic was available on each shift throughout most of the project.

During Phase I, housing and feeding space for the construction and inspection personnel was located in trailers stacked two-high on a barge. At the start of the project, the barge was towed to the site on a very high tide, placed on a gravel leveling bed, and tied off. Although the barge could be totally self-contained for power, water, and sewerage, it was hooked up to the existing site utilities. The average number of contractor personnel was 18 people, counting cook and maintenance staff.

The Phase II contractor chose to move trailers onto the site for his personnel. Because the work involved in Phase II was more extensive, the work force averaged about 30 people.

Blasting

Early in the Phase I project, the primary blasting agent was Tovex water gel explosive. However, in an effort to minimize costs, and finding generally dry rock conditions, the contractor experimented with and then changed to ANFO (ammonium nitrate and fuel oil) prills. This product was the primary blasting agent for the most of the Phase I power tunnel excavation.

The ANFO was delivered to the site in 50-lb bags and blown into the drilled blast holes by a compressed-air hopper mounted on the jumbo. A typical 10-ft round required 350 to 400 lbs of ANFO prill.

Ingnition of the ANFO was accomplished by one cartridge of Tovex 220, loaded and primed at the back of each production hole. The Tovex 220 was also used for the lifters (bottom holes in the round) and the side perimeter holes below the springline. The total amount of Tovex 220 varied from 25 to 150 lbs, depending on the amount of water encountered in drilling the round.

Above the springline, Tovex T-2 water gel was used for the perimeter holes to minimize overbreak. The T-2 explosive is packaged in 24-inch long, 1/2-inch diameter cardboard tubes that can be fitted together to form continuous lengths of explosive equal to 1/4 lb per lin. ft. This product produced excellent results in minimizing disturbance to the surrounding rock. The casts of the crown blast holes can be seen throughout the length of the tunnel, even in blocky ground.

A typical blast round in the 11-1/2 ft-diameter power tunnel was drilled 10 ft deep and pulled 9 ft. Forty to 50 1-7/8 inch-diameter holes were loaded and there were four unloaded 2-1/2 inch-diameter burn holes around the "0" delay hole. (See Figure A-11 for a typical blast pattern.) Powder factors for the ANFO/Tovex 220 rounds averaged about 8.75 lb/yd^3. This powder factor appears high, but, according to the contractor, the massiveness and strength of the rock required a high powder factor.

The blasting pattern, powder factor, and delay pattern used in the Crater Lake Phase I tunnels were developed by varying the elements of the round in a 60-ft test section of the access adit. This testing provided the basis for blasting procedures used throughout the tunnel, although the load was adjusted somewhat for each round to meet the existing conditions.

Blast initiation was accomplished by fuse, primer cord, and Nonel Primadet, non-electric blasting caps. The contractor chose these detonators because of the possibility, although remote, that stray electric currents might be produced by the close proximity of the existing powerhouse and high-voltage electric transmission lines. Typically, the contractor used "0" through "12" delays, with intervals from instantaneous to 5.5 sec. The lifter holes were all double-primed to ensure firing, thus minimizing the potential for a misfired charge at the bottom of the next round.

Blasting procedures in the Phase II work followed the lead of the Phase I operation. ANFO was the primary explosive, using delayed caps with one stick of Tovex gel at the bottom of the blast hole for positive initiation of the ANFO prills. The peripheral holes were fracture controlled using water gel trimming explosive.

The raise blasting deviated from the specifications after the cross section was changed from 10-ft circular to a 9-ft square. The contractor attempted to use trim powder at the periphery and ANFO in main charges, but both gave problems with complete detonation. Most of the blasts were accomplished with 100 percent water gel (Tovex) loading.

UNDERWATER LAKE TAP

Without a doubt, the most unique feature of the Crater Lake Stage was the underwater lake tap using the Norwegian Lake Tap Method. The Long Lake Stage of the Snettisham Project included the first underwater lake tap in North America in 1968. The Crater Lake tap was the fourth North American tap and, at 210 ft, the deepest tap on the continent.

The contractor, Pacific Ventures Inc. retained the Norwegian consulting firm of Norconsult as its lake tap consultant. The Corps retained Mr. Finn Kvingan as its consultant under contract with Polarconsult Alaska, Inc. Mr. Kvingan was also the contractor's consultant during the Long Lake tap. All operations of the lake tap were

under the direction of the contractor's and the Corps' lake tap consultants. A summary report of the lake tap activities prepared by Mr. Kvingan is included as an Appendix E to this report.

A summary of the sequence of activities which led to the successful tap are as follows:

- o Power tunnel was driven to within 60 ft of the expected tap location.
- o Exploratory probe holes were drilled into bottom of lake to locate the exact rock/water interface and to determine fracture density of rock mass near the bottom.
- o Lake tap location was changed slightly to assure that the tap would be made as perpendicular to the rock face as possible.
- o Tunnel was driven to within 12 ft of the bottom of the lake.
- o A large grouting program was initiated, including mixing horse feed with the grout, in an attempt to reduce the volume of water entering the lake tap area.
- o Final blast holes were drilled.
- o Rock traps and a concrete sill in the primary rock trap area were completed.
- o Pumps were installed 2 days prior to the tap to remove water in rock traps.
- o Construction of an "ice plug" immediately upstream of the slide gate was begun approximately 24 hours prior to the tap.
- o The final round was loaded approximately 12 hours prior to the tap.
- o All pumps were removed from rock traps.
- o The final hookup of shot wire was made to slide gate service room.
- o The slide gate was closed, and tunnel and shaft were cleared of all personnel.
- o The final shot was made from the slide gate service room at 1515 hrs., 22 October 1988.
- o Instrument readings indicate that the lake tap was successful.

VI. GEOLOGIC CONDITIONS ENCOUNTERED

PENSTOCK

The geologic conditions which were present at each of the project features are summarized in the following sections. Corresponding geologic maps of the structures are presented in Appendix B. For geologic profiles, see Figures A-5, A-6, and A-7.

Rock Type

The rock in the penstock area consists primarily of quartz diorite, alternating randomly with quartz diorite gneiss (see Figures B-1, B-7, and B-11). The quartz diorite commonly has a gneissic texture with alternating, subparallel, light- and dark-colored bands containing quartz, feldspar, hornblende, and biotite mica minerals. The rock has been cut by basaltic, granitic, and quartz dikes intruded along existing joints and shear zones. Because the majority of the dikes strike approximately N 45° E and dip steeply, and because the tunnel bears S 59° 36'36" E, the dikes appear as near perpendicular banding in the penstock tunnel.

Shears

More than 14 shears were identified that evidenced movement or contained intensive material (predominantly basalt). The penstock showed a higher incidence of basalt-filled shears than did the power tunnel. The few shears with zones of mylonite and broken rock were generally damp and drippy, but did not flow freely. The one exception was a shear at Sta. 68+55 which flowed about 10 gpm from the left wall/crown intersection.

Joints

The preponderance of joints in the penstock tunnel are high-angle joints developed by tectonic stresses. This set of joints strikes N 25° to 35° E and dips 73° to 83° SE. Most of the joints strike within 10° of perpendicular to the tunnel alignment (S 59° 36'36" E). This circumstance, coupled with the steep dip of the joints, leads to a symmetrical banding effect which minimizes fallout along the joint/tunnel interface. There is a minor set of tectonic joints that strike N 33° to 37° E and dip at only 48° E. This set is best exemplified by the single granite dike at Sta. 73+80 and the adjacent parallel joints.

Intrusives

Within the penstock tunnel there were 11 basalt dikes, one granite dike, and one quartz dike. The basalt dikes range from a few inches to more than 3 ft thick and generally completely fill the shears or joints with a tight rock-to-rock contact. One exception is at Sta. 74+64 where the basalt was intruded into an existing shear, as indicated by baking of the adjacent mylonite. The majority of the dikes strike N 25° to 35° E, which places them nearly perpendicular to the bearing of the tunnel. Most of the dikes follow the primary joint system, which dips 73° and 83° SE. The basalt is generally blocky and the dikes exhibit occasional drips and small seeps. The granite and quartz dikes are both tight and dry.

Groundwater

Most of the penstock tunnel is dry, with only occasional drips from blocky basalt dikes. At Sta. 68+55, however, there was a 10-gpm seep near the right wall/crown intersection. This large seep, which was located in a shear only a few inches wide, initially flowed about 30 gpm. The flow gradually decreased and stabilized at approximately 10 gpm after about 2 weeks. When this section of the penstock was expanded for the cast-in-place penstock plug, the flow from this fracture distributed itself

along the numerous subparallel fractures and continued to drip. Even after consolidation grouting, this area continued to drip, although apparently at a lower rate.

POWER TUNNEL

Rock Type

The country rock consists of types associated with the Coast Range Batholith. In the power tunnel area (Sta. 6+65 to Sta. 68+75), the rock consists of quartz diorite and quartz diorite gneiss in an alternating, random pattern. The rock in the power tunnel is predominantly quartz diorite gneiss which is fresh and of high quality. The quartz diorite commonly has a gneissic texture with alternating, subparallel, light- and dark-colored bands or laminations containing quartz, feldspar, hornblende, and biotite-mica minerals. The light bands contain mainly quartz and feldspar; the dark bands contain mainly biotite and hornblende. The contact between the light and dark bands was not a zone of weakness in the rock. The rock has been cut by basaltic, granitic, and quartz dikes intruded along existing joint and shear planes. (See Figures B-2 through B-6.)

Shears

In this 6,210-ft section of power tunnel, more than 50 shears and shear zones were encountered that showed evidence of movement but contained only mylonite or no filling. In addition, there were 25 shears or joints that contained basalt dikes, five shears or joints that contained quartz filling, and one granite dike. The total is 81 major fault discontinuities, an average of one fault per 68 ft of power tunnel.

During the exploration phase of the project, approximately 15 shears were identified that were expected to influence the power tunnel. It is believed that each of these shears was encountered during construction; however, exact identification was difficult because of the great number of shears found in the tunnel. Many of the shears

encountered showed chlorite and/or iron oxide staining, and contained from a trace up to several feet of mylonite and broken and weathered rock. The majority of shears with zones of mylonite and broken rock were damp and drippy but did not flow freely.

Joints

There are two types of joints within the project area: low-angle and high angle. Low-angle joints are formed by stress release from removal of overlying rock or ice. These joints usually parallel the exposed rock surface and die out with depth. High-angle joints were developed by tectonic stresses. Because the power tunnel is located deep underground, there is no evidence of low-angle (stress-relief) joints.

The major feature of the tunnel walls is their "hacksaw blade" appearance where the high-angle joints are prominent and numerous. This strong, primary set of tectonic joints strikes N 25° to 35° E and dips 80° to 85° SE.

The basalt dikes are intruded along these joints, and most of the shear zones also follow this primary joint orientation. The joint planes are generally smooth, with some slickensided surfaces, indicating enough movement to shear the interlocking crystalline mineral grains. Many of the joints have chlorite and/or iron oxide staining, and a few have pyrite crystals along the joint planes.

Some of the joints are wet and drippy, but few actually flow. The basalt in the dikes has its own independent joint system developed from cooling and shrinkage.

Intrusives

Within the power tunnel there were 25 basalt dikes, five quartz dikes, and one granite dike. Of the basalt dikes, 22 had strikes of N 10° to 35° E, approximately paralleling the primary joint system. The other three basalt dikes had strikes of N 10° to 15° W and dipped from 65° to 90° E, with most dipping 80° to 85° E. The basalt dike widths

ranged from 1/2 inch up to nearly 50 ft (at Sta. 44+30), with widths of about 18 inch, 4 ft, and 16 to 20 ft being most common.

The five quartz dikes all had NE-SW strikes and dipped from 75° to 88° E, except for one dike which dipped 84° W. The quartz dikes ranged from 1/4 inch to 4 inches in width.

The single granite dike encountered had a strike of N 33° E and dip of 48° E. It varied in width from 2 to 12 inches.

Most of the heavy water seepage within the tunnel came either from springs along loose contacts between basalt and country rock or from open joints. However, the majority of these contacts are sharp, well-defined, and tight.

The basalt, although massive in some places, is generally blocky as a result of cooling. There are three sets of shrinkage joints that are nearly perpendicular to each other and are independent of the country rock structure. During tunnel driving, rock bolts were installed in some zones of blocky basalt. Additional rock bolts and shotcrete were placed after completion of tunnel driving, in order to avoid long-term fallouts and water plucking action.

SURGE SHAFT

Rock Type

The rock encountered throughout the full height of the surge shaft was of excellent quality and basically the same lithology as that described for the penstock and power tunnel. The predominant type over the whole shaft was gneiss; for many continuous intervals the rock was thick (>1 ft), alternating light- and dark-colored bands of quartz, and biotite mica with areas of hornblende. (See Figures B-9 and B-10.)

Shears

Only one shear area was encountered. This had a mylonite seam of up to 1 inch thick. About 5 ft away, an open joint paralleled this shear and the area also contained lightly fractured pegmatite. The orientation of this shear was such that no remedial action was considered necessary.

Joints

The full height of the shaft exhibited high-angle, tight jointing oriented as described in Section III. The dip of the prominent joint set varied only slightly from the orientation of the shaft centerline. In several areas, one of the walls was actually a continuous face of rock jointing, and, in one instance, this occurred for a distance of almost 30 ft. As the shaft approached the full height, the presence of relatively open stress-relief joints subparallel to the ground surface was noted. However, because these joints were essentially perpendicular to the excavation, they did not cause stability problems.

Intrusives

Two basalt dikes intersected the surge shaft. The first, near the top, was very thin and pinched out within 10 ft of the surface. The other, up to 20 inches wide, was quite blocky but, overall, quite tight. This dike was the source of most of the water flowing into the shaft. This same dike intersects the power tunnel just upstream of the surge shaft adit drift.

Groundwater

The shaft was quite dry overall, with water flowing from the lower basalt dike and some water occurring from the more open joints at the higher elevations of the shaft. Total flow down the shaft was estimated at less than 10 gpm.

LAKE TAP AREA (Sta. 6+60 to Sta. 14+00)

Rock Type

The rock in the lake tap area is structurally and lithologically similar to that described for the penstock and power tunnel, with the exception of the major shear zone intercepted (described below) and the presence of stress-relief joints near the lake bottom. (See Figure B-6.)

Shears

A single shear occurred between Sta. 13+34 and Sta. 13+50, and contained gouge up to to 3 in. wide in a zone of alteration as much as 30 in. wide. The area was shotcreted to provide permanent integrity.

The Hilltop-Cliffside Shear Zone was encountered between Sta. 10+70 and Sta. 8+92. This zone was highly altered, contained gouge and mylonite, and was heavily fractured. Probe holes into the area that was to become the second rock trap also encountered highly altered material, similar to that of the Hilltop-Cliffside Shear Zone.

These rock conditions necessitated the use of extensive support during tunneling lining of the tunnel from Sta. 10+70 to Sta. 9+10, and the relocation of the secondary rock trap. Water flow was not a problem in this zone.

GATE STRUCTURE

Rock Type

The raise excavation creating the gate shaft from the power tunnel to the service room overhead (see cross section in Figure 3) contained the finest quality rock encountered in all excavated areas of the project. It was essentially the same quartz diorite found

throughout the project with its alternating, convoluted bands of light and dark materials, but contained only a few widely separated discontinuities.

Shears, Joints, and Instrusives

No shears or intrusive dikes were encountered. The shaft showed only a few very tight, parallel joints which were the same set of high-angle tectonic joints encountered in all the excavations.

Almost no remedial work was required in this area. Only two rock bolts were placed in the shaft area following initial inspection and logging. A minimal amount of water occurred as slight seepage from some of the joints.

SERVICE ROOM ACCESS ADIT AND SERVICE ROOM

Rock Type

The rock type throughout these excavations was lithologically similar to the rest of the Snettisham rock mass, i.e., quartz diorite gneiss. (See Figure B-8.)

Shears

Five shear zones in the access adit were similar to zones in the tunnel below and were shotcreted for long-term stabilization. These zones were typically iron-stained, with varying degrees of altered rock or mylonite. The most extensively altered zone, between Sta. 3+40 and Sta. 4+30, contained three areas repaired with shotcrete and rock bolts. The most extensive of these shears contained mylonite and very soft gouge up to 18 inches wide in the left rib.

The service room area contained one small shear zone from Sta. 0+10 (access stationing) to Sta. 0+42, healed by a 1/2-inch wide quartz seam with an alteration zone up to 3 inches wide on either side.

Joints

The jointing prevalent in the power tunnel also occurred in the access adit and service room. Some areas of the service room showed the typical steep, tight jointing common to all the rock in this area. The rock, in general, was of the same high quality encountered in the power tunnels, and only a few small shears and other discontinuities were intercepted.

Intrusives

Two basalt dikes were intercepted. The first at Sta. 8+25 was black, massive, hard, and up to 4 inches wide. The other, between Sta. 1+30 and Sta. 1+45, was 6 inches to 14 inches wide and also quite hard, with adjacent zones of altered country rock.

GROUNDWATER OCCURRENCE AND CONTROL

Water was of only minor consequence in the Crater Lake Stage rock excavation work. The water affected construction due to the 12 percent grade. As the upper reaches of the tunnel were attained, the total volume of water near the lower sections created traction problems for the muckers. The roadbed was disturbed and required frequent maintenance.

Although numerous sources of water were encountered, most were damp spots on the walls, with intermittent to steady drips. Actual water flows were very few; the aggregate flow never exceeded 180 gpm, a minor amount even in as small a tunnel as the one constructed. Water in the invert seldom exceeded 3 inches, even in the depressions caused by blasting near the portal. Pumping was not required during tunnel

construction because the slope of the tunnels was more than sufficient for self drainage. A sump pump was employed for the penstock extension, which was driven down slope. Gravity drainage was again established with completion of the penstock at the existing powerhouse excavation.

At Sta. 68+58, the tunnel encountered a joint which was open as much as 2 inches. When first intercepted, the joint flowed an estimated 30 gpm, which decreased to about 10 gpm after several days. Within 2 days of exposure, the flow concentrated on the left wall and issued mostly from a 2-ft-long section of the joint which was open as much as 1-1/2 inch. The flow from the source varied with the weather; e.g. approximately 3 days after a sudden spring thaw or a heavy rain, the flow would increase.

In the area of the Rock Trap Shear Zone (Sta. 68+20 to Sta. 67+00), there were numerous drips, some of which had constant flow at times. The drips and damp areas were spread from approximately Sta. 68+20 to Sta. 67+00, with few totally dry spots throughout the length of the shear zone.

At Sta. 66+78, a concentration of drips occurred along the crown, right of center, at the intersection of a small shear and a basalt dike. The water started dripping at two or three locations and, after a few weeks, spread to more than 20 individual locations, some of them quite constant. Although the water was clear from the first contact, it is possible that some fine-grained materials were washed from fractures, permitting the flow to increase.

The area around Sta. 62+50 was somewhat blocky and showed a few damp spots and one very slow drip. To tie together the individual rock blocks and prevent loosening, three spot rockbolts were placed in the area. Water flowing at approximately 6 gpm was encountered while drilling one of the bolt holes, and this hole continued to flow throughout construction. The adjacent bolt holes produced no water, although length and attitude were similar.

The Tlingit Shear Zone produced the largest single source of water flow in the Crater Lake Stage tunnels, except for the area immediately adjacent to the lake tap. Although the shear crosses the tunnel at approximately a 30° angle to the alignment, thus providing a total exposed length of about 20 ft, all of the water issued from one 2-ft-long section. When first encountered, the fracture was full of clayey fault gouge. 52+75. Water flow started slowly, probably about 5 gpm, built up rather quickly to 30 gpm, and then slowed to 15 gpm, where it remained for essentially the length of the contract. This resulted in a fracture width of 6 inches and a length of 2 ft in the upper left section of the tunnel, halfway between the crown and the springline at Sta. 52+75. Water was handled at this location by laying a sheet of plywood to deflect the water and to prevent it from running down on the mucker operators as they drove past.

Groundwater occurrence was minimal in both surge shaft and gate shaft, with the gate shaft being exceptionally dry. The water in the surge shaft was the accumulation of minimal seeps and drips encountered over the very high raise excavated.

Water was not a problem in tunneling upstream of the gate shaft (including the rock traps), or in preparing the final plug for detonation, except in the immediate area of the final plug and in dewatering the rock traps excavated below invert elevation. The water accumulation in the rock traps was handled very simply by air or electric pumps, or a combination of these, discharging into the tunnel invert where water flowed down the invert.

The probe hole drilling for the final lake tap plug encountered several open joints parallel to the lake bottom with obvious direct connection to Crater Lake. The contractor's lake tap consultants used consolidation/cut off grouting to control the high-pressure water and to solidify the lake tap plug. Flows into the lake tap blast holes were apparently reduced by these measures.

After the lake tap plug was prepared for blasting, the remaining flow from the tap (estimated at less than 100 gpm) was channeled into an invert pipe upstream of the

tunnel lining at the Hillside/Cliffside Shear Zone, diverted to the penstock area, and released out of the access adit portal. A sump was excavated at the portal to settle out fine sediment before the water was released into the fjord.

In summary, the volume and sources of water encountered in the Crater Lake tunnel were approximately as anticipated based on preconstruction investigations.

VII. GROUND SUPPORT REQUIREMENTS

PHASE I CONTRACT

The Crater Lake Phase I contract drawings and specifications provided for the following four types of ground support:

- o Rock bolts
- o Chain-link fabric
- o Shotcrete
- o Steel sets.

Rock Bolts

Rock bolts were the primary support method. A total of 362 bolts, varying from 6 to 15 ft in length and with a combined length of 2,386 lin. ft, were installed in the Phase I construction. Early in the project, the contractor installed 1-inch-diameter Dywidag, Grade 60 rock bolts and tensioned them to 20,000 lbs using a center-pull jack. The bars were received in 60-ft lengths and cut to the specified size. This method proved too time consuming for installation, and the contractor requested a change to torqued bolts. This request was approved on condition that the contractor demonstrate the ability to tension the bolts to the specified requirements. This was demonstrated satisfactorily. The torqued bolts were 1-1/8 inch-diameter (#9 rebar), Williams, Grade 60 rock bolts, 6 and 8 ft long, with machined threads. All bolts were installed in holes that were a maximum of 1/4 inch larger in diameter than the bolt. The bolts were 6 inches longer than the hole (e.g., a 6-ft 6-inch bolt for a 6-ft hole) to provide the thread required for tensioning.

Polyester resin cartridges provided the anchorage for both types of bolts. The back of the hole contained two, fast-set, 12-inch-long cartridges with a set time of 1 to 2 min. The remainder of the hole was filled with cartridges which set up in 20 to 25 min. For

example, in an area requiring an 8-ft bolt, an 8-ft hole would be drilled, an 8 ft 6 inch bar would be used, and two fast-set and six slow-set cartridges would be used for anchoring. This method permitted the bar to be tensioned after the fast-set cartridges set up, and still provided the full-length encapsulation necessary for long-term protection and load distribution. The Williams bolts were tensioned with a calibrated torque wrench. Tension pull tests were conducted on five Williams and one Dywidag bolt randomly selected for this purpose. All the bolts proved to be satisfactory and no additional pull tests were performed.

The specifications required that all rock bolts be installed within 5 ft of the face, before drilling the next round. However, early in project construction it was recognized that two types of rock bolt support were required in this generally excellent quality rock. One type was the immediate support needed if the tunnel encountered ravelling or very blocky rock. The second type was long-term support for areas where there was a potential for continuing stability problems due to adverse discontinuity orientation or frequency. For the areas requiring immediate support, the bolts were installed at the face for the safety of the miners. The long-term support requirement, however, did not appear urgent enough to stop the contractor's mining operation in order to install bolts ahead of the jumbo. Therefore, these bolts were installed behind the jumbo as they could be worked into the contractor's mining cycle.

A third type of bolting evolved during the course of the project. This concerned areas which eventually might require some bolts, but where the timing of the bolt installation was not significant. In fact, most of these areas were not recognized until the tunnel had been open for several weeks, the face had moved well away from the area, and some stress relief had occurred. However, early in the project, the contractor had been informed that some supplemental bolts might need to be installed at the end of excavation and prior to completion of the tunnel. The contractor had agreed, because bolt installation would not interfere with the excavation cycle.

Chain-Link Fabric

The specifications required that the contractor be prepared to furnish and install No. 6 gauge, 2-inch by 2-inch, chain-link fabric as a supplement to rock bolts for ravelling ground in the tunnel. Chain link was installed in the new machine shop excavation across a 2-ft-wide shear zone which ravelled. This area was shotcreted under the main contract.

Steel Sets

The Phase I contractor furnished 10 straight-legged steel sets to the project in the specified W4 by 13 size. As generally expected prior to construction, no ground conditions were encountered which required steel sets in Phase I of the Crater Lake Stage.

Shotcrete

The specifications required that the contractor apply wet-mix shotcrete as part of the ground support system. During actual Phase I tunnel driving, the application of shotcrete was not needed for immediate support because the rock was competent. However, numerous shears containing varying widths of mylonite and crushed rock required stabilization to preclude plucking and slow ravelling that could progress to more serious instability. These areas were mapped and designated for shotcreting (see Table 2) with suitable overlap onto the adjacent high-quality rock. Most of the zones crossed the tunnel at an acute angle.

Actual application of this shotcrete was delayed until completion of the Phase I excavation, when it was felt that an efficient shotcrete operation would result in a higher quality product. Bagged shotcrete mix, a new Eimco wet-mix pneumatic shotcrete machine, and a previously Corps-approved accelerator (HPS, manufactured by Gilbertson & Co. Ventures, Inc.) were shipped in. Several problems were then encountered.

TABLE 2 Designated Shotcrete Areas - (Phase I Contract)

Station Left	Station Right	Design Thickness (inches)	Remarks
A16+67	A16+73	4	No work; dry *a
74+72	74+57	4	No work; dry
65+55	65+85	4	No work; damp *a
60+45	60+80	4	No work; dry
60+22	60+32	4	Shotcrete applied *b
59+65	59+78	4	Shotcrete applied
59+35	59+65	4	Shotcrete applied
52+60	52+98	6	No work; very wet *a
51+85	52+15	4	No work; wet *a
50+98	51+25	4	Shotcrete applied
49+52	49+80	4	Shotcrete applied
48+35	48+65	4	Shotcrete applied
47+65	48+00	4	No work; very wet
44+35	44+85	4	Shotcrete applied
41+65	41+85	4	Shotcrete applied
39+55	39+75	4	No work; wet
39+00	38+15	4	No work, very wet
34+60	34+80	4	No work; wet
33+82	34+10	4	No work; wet
31+20	31+45	4	Shotcrete applied
30+80	31+05	4	Shotcrete applied
29+90	30+15	4	No work, dry
28+45	28+60	4	Shotcrete applied
27+85	28+15	4	No work; dry
27+57	27+87	4	No work; dry
25+60	26+02	4	No work; very wet
25+40	25+68	4	No work; very wet
19+90	20+20	4	Shotcrete applied
18+80	19+25	4	Shotcrete applied

The width of the designated areas varies from approximately 6 ft to 40 ft. according to the geology

a. Areas noted as dry, damp, wet, or very wet during Phase I construction may have a different condition during the Phase II Contract.

b Shotcrete application did not meet the compressive strength required by specification Shotcrete applied to the crown was thinner than required

Although initial panels of shotcrete applied at the portal area tested within the specified range of strengths, cores of the shotcrete applied in the tunnel tested below the minimum strength. Additional panel tests indicated that increased amounts of accelerator resulted in significantly reduced ultimate shotcrete strengths. Further, the valving system on the shotcrete machine made adding the proper amount of accelerator at the nozzle very difficult. In addition, the contractor attempted to shotcrete above the fan line without removing the line. Because of the acute angle, this led to segregation of the shotcrete and unacceptable volumes of rebound.

Several areas within the tunnels were shotcreted. (See geologic maps in Appendix B for locations.) However, because the contractor was unable to determine the cause of the strength failures indicated by the in-situ core tests, he proposed that no payment be claimed for the completed work and that the remaining shotcrete work be deleted from his contract. The government paid a percentage of the unit cost for the placed shotcrete that would be functional. There was no further use of shotcrete during the Phase I contract because there was no indication that the contractor would be able to meet the specifications, and also because the follow-on contract for Phase II included shotcrete.

PHASE II CONTRACT

The same types of ground support were specified in the contract for Phase II work as for Phase I. These were rock bolts, chain-link fabric, shotcrete, and steel sets. In contrast to Phase I, all available types of supports were used in the second contract.

Rock Bolts

Again, rock bolts were the primary support method and were used extensively throughout the duration of the rock excavation. The log of rock bolt placements for Phase II, summarizing the number, location, and length of bolts, was prepared by the Contractor and is on file with the Corps of Engineers

The contractor used both Dywidags and Williams rock bolts. However, most of the bolting was performed with the Dywidags. The Williams bolts were government-furnished, 1-inch-diameter, Grade 60, 8-ft-long, and machine threaded. The Dywidag bolts were the contractor's own procurement, 1-inch-diameter, Grade 60, and 20 ft long for cutting to length as required.

The contractor preferred placing Dywidags since they were rotated left-hand into the resin cartridges using regular drilling tools. The majority of the bolts were 6 ft or 8 ft long with some longer.

As in the Phase I work, polyester resin cartridges were used to anchor the permanent bolts in the tunnel. However, the contractor was permitted to use "split set" rock bolts just upstream of the concrete plug because this area would receive a concrete lining.

Steel Sets

Steel sets were placed in the Phase II work after the power tunnel excavation entered the Hilltop-Cliffside Shear zone. Rock bolts with shotcrete overlay were recommended

to the Corps by the on-site L&A representative. However, the contractor did not have an approved shotcrete available and was, therefore, in nonconformance with the specifications.

A portion of the right rib that had been bolted, but, which was without a shotcrete cover, sloughed into the tunnel leaving a void in the wall about 4 ft deep. Mylonite seams bordered the slough area, and steel sets were chosen to restrain the area.

Straight-legged W4 by 13 steel sets were erected in the area and lagged with 3-inch fir lagging and wedges. Only the immediate area of the slough was taking load, and if shotcrete had been available, it is probable that no steel sets would have been required.

<u>Shotcrete</u>

In the Phase II work shotcrete was placed in several different areas with varying degrees of success. The first placement of shotcrete was to provide support for fractured/sheared material encountered during power tunnel excavation. The last placement of shotcrete was in areas of the power tunnel designated as needing repair in Phase I, but which were not successfully repaired then, and also in some areas of the service room access tunnel.

Two different pre-packed shotcrete mixes were used by the Phase II contractor. The first was packaged in 100-lb bags and did not result in an acceptable product. The second was packaged in 3,000-lb bags and gave very good results. These mixes are described in Section X.

The problems involved with the shotcrete initially proposed and attempts at its use are discussed in detail in Section IV under the discussion of the Hilltop-Cliffside Shear Zone. Shotcrete was used successfully in the machine shop area where it was applied in the shear zone exposed during Phase I excavation.

The placement of the second type of shotcrete proceeded with few difficulties. It was initially used to cover the small exposed shear zones in the service room access adit, and was used extensively to cover the problem areas shown in Table 2. The preparatory work, cleaning the surface and diverting water, was according to specification, and the subsequent placement reflected the quality of work. The surface was washed with a high-pressure water jet. In areas of seepage, holes were drilled, flexible pipe was installed, and quick-set grout was used to seal the pipes. This treatment was effective in eliminating most water problems.

Shotcrete placement at the Phase I areas listed in Table 2 was acceptable. The nozzlemen were experienced and used good techniques. The nozzle was consistently oriented near perpendicular to the surface of the rock and held about 4 ft from the rock. The lower levels were shot from the invert, and the upper portions were applied from a wooden planked platform constructed over the bed of a mine truck.

The shotcrete was mixed outside of the tunnel and then transported to the nearest muck bay using air-rotated agitator trucks. After reagitating at the muck bay to eliminate segregation, the shotcrete was transported with a mucker to the shotcrete pump. Shotcrete was batched in 1.5-yd increments to ensure placement within the time specified.

Figure A-12 summarizes shotcrete placement in Phase II area including dates, quantities of shotcrete and accelerator, and comments. Procedures for placement was as described for the Phase I shotcreted areas.

Supplementary (Tunnel Plug Area)

The contractor asked to use split sets and strapping (mine ties) as supports in the final tunnel plug enlargement. These were approved by the Corps with L&A's concurrence because the area was to be lined with concrete.

VIII. GROUTING

No grouting was done during the Phase I construction.

The Phase II construction included grouting in the following four areas:

- o Water control grouting at the lake tap area
- o Crown/contact grouting of the tunnel lining upstream of the gate shaft
- o Crown/contact grouting at the gate structure
- o Consolidation grouting and crown/contact grouting of the tunnel plug area.

All grouting was done in conformance with Contract Specification, Section 2E, with a mix design in conformance with Figure A-13 which shows the relation of expansion to water/cement ratio. A Febgrout percentage of 0.75 percent was used for all grouting because it most nearly centered an area between the allowable 3-percent to 5-percent expansion for water/cement ratios of 1.0 to 4(+).

LAKE TAP AREA

At the lake tap area grouting was done only to reduce water flow through joints from the lake bottom to the power tunnel area, and was directed by the contractor's lake tap consultants. A series of holes was drilled around the plug area and, they were high-pressure grouted. Several grouts were used: neat cement grout with calcium chloride; a sand-cement grout; and even a cement grout with horse feed as a swelling additive. Pressures of up to 100 psi were used to overcome the pressure of the full lake head. This grouting was not done in conformance with the Corps of Engineers specifications, but was varied by the consultants to meet the encountered conditions.

TUNNEL LINER

The tunnel liner in the area from Sta. 10+70 to Sta. 9+10 was contact grouted to ensure that voids between the concrete liner and the rock surface were filled. In this area, segments of steel grout pipe were placed at locations that would best fill the deep overbreak and fallout areas of the crown and rock walls. These pipes were placed at various locations from invert to crown, as required, prior to concrete placement, and were cut to fit between the inside face of the concrete and the face of the rock. Grouting was accomplished using neat cement grout with water/cement ratios ranging from 5:1 to 1:1. Pressure never exceeded 10 psi, and the total grout take was 2.5 cu. yds.

GATE STRUCTURE

Grouting at the gate structure was performed in a manner similar to that for the tunnel lining area, except that grout pipes were not provided below the springline. The rock in the area was excellent quality, and the excavation very close to the design line. The grout pipes, therefore, were placed basically as detailed on the original design drawing, and grouted after the concrete was placed. (See Figure A-14.)

The ends of grout pipes (at the rock face) were cleaned with a jack-leg percussion drill to ensure a good interface between the concrete and the rock. Grout was placed through packers in grout pipes, working from the lowest elevations to the highest.

The upstream portion of the gate structure from the upstream face of the concrete to the shaft lining required considerably more grout than the downstream portion (from the shaft lining to the downstream face of the concrete). The grout was pumped at just a few psi above that necessary to overcome static head at the location being grouted. At all locations, the grout was mixed at 5:1, water to grout, by volume.

Upstream of the gate, the shaft lining took 10 cu ft of grout, with grout flowing readily from the packed grout holes along the interface between the concrete liner and rock to the upstream face indicating a definite void at the apex of the lining. The area was pumped twice, with the grout from the first pumping allowed to set while the downstream portion was grouted, and then repumped.

The downstream portion of the lining was very tight against the rock, taking only a approximately 5 cu ft of grout to fill the overhead concrete-rock interface. The grouting proceeded in classic textbook manner, with grout-flow returning from the next hole in the sequence as grouting progressed from the lowest elevation hole to the highest. Grouting continued progressively uphill, filling the overhead void hole to hole. The last pumping was to the highest overhead hole, which, after showing grout return, was valved off. Grouting continued until pressure started to rise at constant flow. This occurred almost immediately.

The downstream portion of the lining is more critical than the upstream portion, because it is in the dewatered area when the gate is closed and is subject to horizontal thrust from the closed gate. The effectiveness of grouting in this critical area was an especially important accomplishment.

TUNNEL PLUG AREA (CONSOLIDATION/CUT OFF GROUTING)

The tunnel plug area (see Figure A-15) and the adjacent upstream area required consolidation/cut off grouting prior to concrete placement, and crown grouting after lining and plug placement.

Consolidation/cut off grouting started with a curtain at Sta. 69+18 and proceeded upstream to incorporate seven rings. Rings were located at Sta. 69+18, Sta. 68+80, Sta. 68+10, Sta. 67+85, Sta. 67+70, Sta. 67+55, and Sta. 67+25. The grout holes at Sta. 69+18 and Sta. 68+10 were placed perpendicular to the tunnel centerline. All holes upstream of that were placed at an angle of approximately 40° to the tunnel

centerline. The grouting was done according to the contract requirements and went smoothly. However, the hours it took to conduct both pressure testing and grouting far exceeded those assumed in the contract for pay item quantities.

Grouting was done with a duplex-displacement grout pump pumping from a 30-cu ft, continuously agitated holding tank, which received intermittent batches from a mixing tank. The discharge line from the pump(s) was teed, with one line returning to the agitator tank and the other line going to a manifold for connecting lines to various holes being pumped. Both of these lines were valved so that the amount of flow either recycled or discharged to grout holes could be controlled. Adjusting the two valves simultaneously allowed adjustment in flow and pressure.

A certified gauge reading from 0 to 100 psi was located downstream from the discharge valve. Measuring the height differential between the gauge and the hole being pumped allowed computation of the pressure at the hole connection.

The typical pumping procedure involved setting Pump No. 1 at its lowest speed, and then using valves 1 and 2 to direct grout flow and establish pressure. With the grout line connected to a grout hole using a rubber packer, the valve on the grout supply line was opened fully, and the pressure was regulated by throttling flow through the valve on the line returning to the agitator tank, therby varying the amount of grout bypassed and returned to the agitator. Pump No. 2 was never used, but was kept on standby.

Holes were washed and pressure tested with clear water prior to grouting, and the pressure test results were used as a guide for grouting. Flows were established from the recorded volume change in the agitator tank for a specific time interval, usually 5 to 10 minutes. At all holes, grouting was terminated when grout take became less than 1 cu ft of solids per hour.

The results of the consolidation/cut off pressure testing and grouting are recorded in the grout curtain summaries in Appendix G that follow (Figures G-1 through G-8).

These summary figures show quantities of grout taken, as well as time pumped, for each hole at each ring. The consolidation/cut off grouting was, from all indications, effective. As the summaries show, grouting was completed in accordance with the original plans and specificiations and with few complications. Pressure tests of supplementary, split-spaced holes always indicated tight rock conditions before grouting was completed in any area.

The first two rings and the apex of the tunnel plugs (Sta. 69+18 and Sta. 68+80) took minimal grout quantities except for holes 7 and 9 at Sta. 69+18 and holes 5, 7, and 14 at Sta. 68+80. Supplemental holes drilled adjacent to these (designated with an "A" following the number) showed by their refusal to accept grout that the first grouting was probably successful.

The driller's logs for holes 1 and 2 at the grout curtain at Sta. 68+10 indicated a soft, fractured zone approximately 20 ft from the rock surface, and the grout take reflected this. The supplementary hole here (1A) showed minimum take. The grout holes in the left wall were parallel and intercepted a set of fractured rock joints. They showed considerable grout take, particularly holes 6, 10, 14, and 16. However, supplementary holes here (14A and 16A) indicated effective initial grouting.

Considerable grout was taken by holes 3, 5, 9, 11, and 13 at Sta. 67+85. Split-spaced supplementary holes (3A and 11A) were quite tight.

The overhead holes (19 and 20) at Sta. 67+55 took large amounts of grout and produced flowing water under pressure during both initial and follow-up grouting. (The static pressure of water in the holes was 45 psi.) The holes continued to take grout during supplementary grouting and grouting was terminated at the minimum requirement of less than 1 ft^3 of solids per hour.

The grout curtain at Sta. 67+25 (with supplemental holes at Sta. 67+30) did not take great quantities, except for holes 4 and 20. A considerable amount of grout was lost

to surface leaks. Probably less than half of the 33.0 ft^3 of grout pumped actually penetrated into the hole. Supplementary holes showed all areas significantly tighter after initial grouting.

Although the consolidation/cut off grouting in the tunnel plug area was completed according to specifications and used the best possible techniques and procedures, water leakage from the rock was reduced, but not totally eliminated. Therefore, it must be assumed that there are fractures in this highly broken shear zone that have not been completely sealed, even with these careful techniques. If water can leak into the tunnel, it must have some pathway to the ground surface. Because this zone will be subjected to almost the full hydraulic head of the project, careful monitoring for leakage will be required after the tunnels are filled and the project is operating.

TUNNEL PLUG AREA (CROWN/CONTACT GROUTING)

Contact grouting between the rock wall surface and the outer concrete surface of the tunnel plug was begun at 1256 hrs on 24 October 1988. Subsequent contact grouting for the interface between the steel penstock and the tunnel plug contact was done on 30 October 1988. The contact grout was mixed in accordance with the chart prepared by The Corps of Engineers' Troutdale Laboratory using a 0.75 percent additive to give 3 to 5 percent expansion for 1:3 to 1:5 mix, as shown on Figure A-13. The cement used, however, was bulk cement and not the cement tested with the Febgrout by Troutdale Laboratory because the tested cement was not available.

The same grouting equipment was used for the rock/concrete interface as had previously been used for consolidation grouting; however, a hand grout pump was used for the contact grouting between the penstock liner and the tunnel plug concrete. This pump was adequate because virtually no grout was taken in this process.

The contact grouting of the rock/concrete interface at the tunnel plug was begun by pumping into the 2-inch-diameter supply line on the left (looking upstream), which had

been cast into the plug, in accordance with the design. After grout was returning in the left-hand return line, the line was closed, and pumping continued until grout returned in the right-hand supply line. The right-hand supply line was then valved off until grout was flowing from the right-hand return line. After this, the right-hand supply line was reopened and full grout flow verified. At this time, the pump was connected to both right- and left-hand supply lines and pumping continued. No air vent return line was provided in the design. This would have been of no value since the line was within the concrete, and air could not get to it.

Pumping on both supply lines was initiated at 20 psi. The maximum pressure required to reach the top of the highest concrete at Sta. 68+80 was approximately 17 psi above the pressure at the discharge manifold (using a density of approximately 90 pcf for 2:1 water/cement mix). The intake line was changed as quickly as possible, but seepage of grout from the downstream face of the plug was noted shortly after pumping began, and sealing was attempted with rags and lead wool.

Pumping was interrupted at 2057 hrs when it was determined that no flow was occurring. There was a plug in the pump intake line, and neither pump could be used. The intake line was changed as quickly as possible, but the pump was down until 2205 hrs. At approximately 2130 hrs the supply and return lines on both sides were allowed to drain back to avoid initial set in the manifolding. Pumping was resumed at 2205 hrs, and the same startup procedure was repeated to purge the manifold.

Pumping was continued until 0023 hrs, (the morning of the next day) during which time a very heavy flow of grout continued from the interface between concrete and rock at the tunnel's downstream face (Sta. 69+50). At 0023 hrs the valve between the pump and the grout connection was closed, and the grout was allowed to set without being pumped until 0120 hrs. This allowed an initial set to see whether a seal would develop at the downstream face. The pressure dropped back and remained at 10 psi during this time.

Pumping was renewed at 0133 hrs at 20 psi with a much reduced take. The downstream face of the plug was not leaking. Pressure was increased to 25 psi at 0230 hrs, but, when leakage started again on the downstream face, the pressure was dropped to 20 psi and held there as the leakage stopped. The mix was thickened to a 2:1 mix; however, very little of it was pumped from the agitator tank, since the grout take was rapidly decreasing. The rate of grout pumping rapidly declined between 0230 hrs and 0330 hrs, and was at refusal between 0330 and 0400 hrs. Grouting stopped at 0422 hrs.

It is our understanding that the basic design for the concrete plug came from the Dworshak Dam Project which had a similar type of tunnel plug contact grouting system. However, it was L&A's opinion that although the grouting system reportedly worked well at Dworshak, the lack of a positive method to check the performance of the grout system prior to tunnel filling constituted a potential problem. This problem was confirmed during the initial tunnel filling. More than 50 gpm leaked through the plug, most of it from the contact between the concrete and the rock above the springline (See Section X).

Grout pumping was started in the tunnel lining upstream of tunnel plug (Sta. 68+75) on the day shift on 25 October 1988. Table 3 summarizes this operation. (See Figure A-15 for layout.) It proceeded upstream from the interface between the tunnel plug and the tunnel lining to the upstream end of the tunnel lining. Grouting in this area involved pumping from downstream holes (at lower elevation) to upstream holes, and plugging off the holes upstream as they showed flow of grout. The pump hole location was moved progressively upstream as the upstream holes showed grout flow and were plugged off. Grout holes were pumped to refusal or to less than 1 cu ft of solids per hour. Approximately 1 wk after grout placement, all grout holes were redrilled to provide liner drain holes, as required in the contract. The following summary gives a chronological account of the grouting of the tunnel liner. Approximately 1 week after the grout placement, all grout holes were redrilled to provide liner drain holes required in the contract.

TABLE 3 Summary of Contact Grouting: Upstream of Tunnel Plug Sta. 68+75 To 67+40

Hole Number	Pumping Times	Pressure at Discharge Manifold (psi)	Remarks
25 October 1989			
1A	0820 To 1245	45/65	Grout show & shut off @ 2A, 1B, 3B, 5B, 6B, 7A, 7B - Grout sample = 79#/ft^3, 8B, 2E, 3E
2B	1245 To 1312	50	Shut off 2B - No take
3A	1315 To 1327	50	Shut off 3A
4A	1330 To 1335	50	
4B	1335 To 1346	50	Shut off 4B / Reconnect 4A
4A	1346 To 1358	50	Shut off 4A
5A	1359 To 1410	50	Shut off 5A
6A	1413 To 1424	50	Shut off 6A
8A	1425 To 1445	50	Grout sample = 79#/ft^3 - Shut off 8A
9A	1447 To * (abort)	50	Packer Failure - move to 9B
9B	1447 To 2037		Grout show & shut off 1515 hrs - 4E, 5E, 6E, & 7C 1550 hrs - 8E 1555 hrs - 11C 1610 hrs - 12C, 13C, 14E, 15E, & 16E 1625 hrs - 12D & (2G, 2H,& 2I - not pattern holes) 1650 hrs - 13E 1740 hrs - 2C, 4C, 7C, 3D, 5D & 6D 1745 hrs - 17D (Grout @ 78#/ft^3) 1820 hrs - 18D 2000 hrs - Grout @ 75#/ft^3 Moving to 11A
11A	2045 To 2117	40	No take - shut off

TABLE 3 Summary of Contact Grouting (Continued)

Hole Number	Pumping Times	Pressure at Discharge Manifold	Remarks
12A	2119 To 2139	40	No take - switch back to 9B
9B	2140 To	40/50	Pressure increased to 50 psi @ 2335
26 October 1989			
9B cont'd	0030	50	Hole take < 1 ft^3/hr
10B	0040 To 0052	40	No take
13A	0052 To 0059	40	No take
11B	0102 To * (abort)	-	Packer leak / switch to 12B
11B	0109 To 0124	40	No take
11B	0157 To 0207	40	No take
13B	0210 To 0239	40	Refusal / shut off
1C	0308 To 0322	40	No take
1D	0322 To 0335	40	No take (Grout sample @ 76#/ft^3
7E	0338 To 0347	40	No take / shut off
9E	0349 To 0359	40	No take / shut off
10E	0400 To 0414	40	No take / shut off
11E	0416 To 0425	40	No take / shut off
12E	0427 To 0437	40	No take / shut off
2D	0439 To 0450	40	No take / shut off
4D	0451 To 0501	40	No take / shut off
7D	0511 To 0522	40	No take / shut off
8D	0528 To 0538	40	No take / shut off

TABLE 3 Summary of Contact Grouting (Continued)

Hole Number	Pumping Times	Pressure Discharge Manifold	Remarks
9D	0543 To 0553	40	No take / shut off
10D	0555 To 0605	40	No take / shut off
11D	0607 To 0617	40	No take / shut off
2C	0619 To 0630	40	No take / shut off
Shift Change			
3C	0653 To 0702	50	No take / shut off
5C	0704 To 0717	50	Pumped to refusal (1.0 ft^3/hr
6C	0719 To 0731	50	No take / shut off
8C	0732 To 0744	50	No take / shut off
9C	0747 To 0758	50	No take / shut off
10C	0804 To 0815	50	No take / shut off
14A	0816 To 0826	50	No take / shut off
15A	0827 To 0840	50	No take / shut off
15B	0845 To 0857	50	No take / shut off
16C	0946 To 1012	50	Pumped to refusal (0.2 ft^3/hr
13D	1020 To 1031	50	No take / shut off
14D	1038 To 1047	50	No take / shut off
15D	1048 To 1100	50	No take / shut off
14C	1107 To 1117	50	No take / shut off

TABLE 3 Summary of Contact Grouting (Continued)

Hole Number	Pumping Times	Pressure Discharge Manifold	Remarks
15C	1120 To	50	1140 hrs - changed mix to 2-1/2:1
			Grout show & shut off
			1210 hrs - 19D
			1245 hrs - 20C & 21D
			1247 hrs - changed mix to 2:1
			1251 hrs - Grout density @ 83#/ft^3
			Grout show & shut off
	increased to	60	1320 hrs - 12E - Increase pressure to 60 psi
			30 psi recorded on gage @ Hole 20D
			Grout @ 24D / shut off
			Hole 20D showing 35 psi (1445 hrs)
			Hole 20D showing 30 psi @ 1515 hrs
15C	Continuing		1549 hrs - Grout @ 26D & 27D / shut off
			1617 hrs - Grout @ 21C / shut off
	increased to	65	Increase pressure to 65 psi @ 1617 hrs
			Hole 20D - showing 42 psi @ 1646 hrs
			Grout @ 84#/ft^3 - 1653 hrs
			Increase pressure to 70 psi @ 1657 hrs
	increased to	70	1703 hrs - Grout @ 25C / shut off

TABLE 3 Summary of contact Grouting (Continued

Hole Number	Pumping Times	Pressure Discharge Manifold	Remarks
			1713 to 1737 hrs - Grout observed @ 13A, 28D, 28C, 23C, & 6A / shut off
			1732 hrs - Hole 20D shows 44 psi
			1753 hrs - Grout @ 5A / shut off
Shift Change @ 1853 hrs.			
			2022 hrs - shut down - clean pump/hoses
			2040 hrs - Restart pumping
			2157 hrs - moved gage from Hole 20D to Hole 29D equal or similar to 10 psi
			2256 hrs - change mix to 1.5:1
	2341		Grout take equal or similar to 1.3 ft^3/hr - move to 20D
20D	2349 To	70	
27 October 1989			
20D cont'd	0020		Grout < 1.0 ft^3/hr
22D	0030 To 0051	70	Grout < 1.0 ft^3/hr
23D	0052 To 0102	70	No take / shut off
29D	0104 To	70	0111 - Heavy grout flow @ 31D / shut off
			Grout flow @ 31D, 30C, 31C, 30D, 0135 33C, 32D, & 33D - shut off
			0138 hrs - Grout flow from concrete/rock
			interface @ upstream end of liner

TABLE 3 Summary of Contact Grouting (Continued)

Hole Number	Pumping Times	Pressure Discharge Manifold	Remarks
	0227		Shut down to allow grout set-up @ upstream end of grout liner. Pressure reduced to 25 psi @ 0145 hrs
16E	0230 To 0244	40	No take
17E	0245 To 0255	40	No take
18E	0301 To 0311	40	No take
19E	0314 To 0325	40	No take
17C	0326 To 0342	40	Pumped to refusal < 0.25 ft^3 grout
29D	0347 To	25	Repumped to check seal @ upstream end of liner - Pressure increased from
		increased to 35	25 psi to 35 psi @ 0427 hrs - leaking restarted @ end of liner - Pressure reduced to 25 psi/shut off
	0511	increased to 25	@ 0511 hrs
18C	0514 To 0533	40	No take / shut off
20E	0541 To 0551	40	No take / shut off
21E	0557 To 0607	40	No take / shut off
22C	0611 To 0620	40	No take / shut off
20E	0624 To		
Shift Change @ 0630			
	0644	40	No take / shut off
22E	0647 To 0700	40	No take / shut off
23E	0701 To 0713	40	No take / shut off
22D	0715 To 0725	40	No take / shut off
26E	0727 To 0737	40	No take / shut off

TABLE 3 Summary of Contact Grouting (Continued)

Hole Number	Pumping Times	Pressure Discharge Manifold	Remarks
27E	0739 To 0749	40	No take / shut off
28E	0751 To 0802	40	No take / shut off
19C	0804 To 0817	40	No take / shut off
24C	0822 To 0845	40	No take / shut off
26C	0846 To 0856	40	No take / shut off
27C	0857 To 0907	40	No take / shut off
29C	0910 To 0920	40	No take / shut off
32C	0922 To 0935	40	No take / shut off
15C	0940 To	40	
	increased		Grout sample @ 1110 hrs = 90#/ft^3
	1225 to	70	Pumped to refusal - last hole.

IX. INSTRUMENTATION

TAPE EXTENSOMETERS

During the Phase II work, tape extensometers were installed in two areas: within the tunnel section where it crossed the Hilltop-Cliffside Shear Zone; and within the tunnel plug area after it was excavated to a final, large cross section. The readings were taken by the contractor's Quality Control personnel.

The extensometers were installed in normal fashion, using a percussion drill to make a hole for the head anchor. The anchor holes in the area of the Hilltop-Cliffside Shear Zone were drilled using a hand-held jack-leg drill because nothing else was available to drill perpendicular to the tunnel centerline within the standard-sized tunnel cross section. The anchor holes in the tunnel plug area were drilled using the jumbo.

The readings in both areas were of no quantitative value because loose anchors and haphazard monitoring made plots of deformation vs time impossible. An attempt was made to reset the loose anchors; however, readings indicate that this effort was not successful.

X. TUNNEL FILLING

The tunnel-filling procedure was preceded by a ground survey to establish the probable drainage pattern of the surface area adjacent to the penstock/power tunnel, downstream of the surge shaft location. This area was felt to be the probable location of any leakage from the power tunnel. Appendix D describes the rationale and procedure for this surveillance.

Actual filling of the power tunnel was begun on 8 April 1989 using a tunnel filling procedure prepared by the Hydraulic Section of the Corps Alaska District. The filling was planned to occur in six nearly equal increments (lifts) with either Corps staff or consultants stationed at critical locations to observe the effects of the filling. For each lift, two Corps personnel were helicoptered to the service room to operate the upstream gate, two Corps personnel were at the tunnel plug area monitoring a pressure gage, and two representatives of L&A alternately monitored the tunnel plug/penstock area and surface flow patterns. Additional Corps personnel were at the access portal and the spherical valve, and the Corps team leader managed the group by radio and telephone from the powerhouse control area.

The mountainous surface area above the penstock was monitored by helicopter using a slow-speed, back-and-forth and up-and-down pattern over the area of concern. As weather permitted, The pilot and an L&A representativemade two flights per lift. In addition to the helicopter monitoring, continuous measurements were taken on the weirs and culverts established to monitor the surface-water flow from the area of primary concern.

During the filling operation, there were no surface indications of tunnel leakage, either by increased flow over the weirs and culverts, or by observed upland surface flows or water discoloration. On the other hand, the rock/concrete interface at the downstream end of the tunnel leaked with the first lift, with a gauge pressure at the downstream end of the tunnel plug of less than 40 psi. Leakage from the downstream face increased

progressively with the water pressure increase until it reached its maximum, with full-tunnel pressure, of approximately 50 gpm (similar or equal to 382 psi at tunnel plug). The quantity of flow from the face was determined by measurement at the weir set up just outside the access portal, which thereby measured the flow of water from the tunnel in the penstock/tunnel plug area.

In addition to leakage from the downstream face of the tunnel plug, considerable leakage was occuring from cracks in the floor, walls, and roof of the vehicular service tunnel inside the tunnel plug. These leaks appeared to be coming from a cold joint in the concrete, but this is not certain because details of the concrete placing procedure in this area were not available to the authors. There was no convenient way to determine what proportion of the leakage was coming from the cracks, and what was from the downstream face of the plug.

In summary, it appears that leakage from the tunnel to the ground is not of immediate concern, although it could develop with time. On the other hand, the leakage from the downstream face of the tunnel plug indicates that the contact grouting, as conceived and executed, has not worked adequately for this project. Remedial grouting should be accomplished. (See note below.)

NOTE:
Subsequent to the initial presentation of this report, it was determined that, in fact, the grouting system used at Dworshak was not what was specified and detailed for Snettisham. The air vent line was installed and protected during concrete work to ensure air release. Also, the grout was pumped uphill in stages from multiple grout pipe connections, rather than from a single hook-up. This system precluded the grout leakage from the downstream face as experienced at Snettisham.

XI. SUMMARY AND RECOMMENDATIONS

SUMMARY

The Crater Lake Stage of the Snettisham Hydroelectric Project was built between 1985 and 1989. The project added 31 megawatts of non-polluting, renewable, electric power for Juneau, Alaska, and the surrounding area.

Foundation conditions for the Crater Lake Stage were excellent, permitting the power and penstock tunnel and the shafts to be constructed essentially unlined. The basic rock type throughout the project is a high quality, quartz diorite gneiss with randomly spaced, subparallel, basalt dikes. Two shear zones more than 50 ft wide were encountered and were lined with concrete to eliminate plucking and erosion during operation. A dominant, high-angle joint set striking N 25° to 35° E was encountered which essentially controlled the roughness of the tunnel in spite of the contractors' best efforts to provide smooth-wall blasting. Small shears and closely spaced joints which produced blocky ground were shotcreted to assure that the rock traps would not fill prematurely with debris washed down the tunnel.

Both of the contractors for this project chose to use the drill-and-shoot method of excavation, but, due to the high strength of the rock and the steep grade of the tunnel, they were somewhat restricted in the methods available to them.

The use of a Title II contractor (L&A) to assist the Corps in its "design as you go" ground support was very effective. As a result, the project, for the most part, used only the support which was reasonable for the ground excavated and suited to the geologic conditions actually encountered. It has been everyone's opinion that the savings to the project were appreciable. The project also benefited by the "as-needed" availability of the Title II contractors expertise on an arrangement which also minimized costs.

RECOMMENDATIONS

The geotechnical recommendations for the operation of the Crater Lake Stage are minimal, due primarily to the overall excellence of the Snettisham Project rock. The recommendations are as follows:

1. Continue to monitor the hillside south of the powerhouse for possible leakage from the Crater Lake power tunnel. Grouting and lining of the rock trap probably reduced the potential for leakage to the outside from this area. However, because water continued to flow into this area through grout and drain holes after completion of construction, there is still some open path from the tunnel to the rock mass. This was the same area where leakage would vary with the outside weather, e.g. three days after a heavy rain, the flow would increase. Although no hillside leaks were noted during the initial tunnel filling, long-term pressurization could produce some leaks which could erode joint and shear fillings. Periodic evaluations of seepage from the hillside would be prudent.
2. Perform remedial grouting through the penstock plug. (See note below) It is our opinion that the grouting system which was designed to grout the concrete-rock interface in the penstock plug did not perform adequately. Although the leakage around the plug is only 50 gpm, calculations have shown that the almost 1,000 ft of hydrostatic pressure on the plug will produce water velocities which could erode the concrete. A remedial grouting program, such as the one provided to the Corps by L&A at the time of the tunnel filling, should reduce the leakage to an acceptable level. However, seepage through the plug should be monitored for the life of the project to assure that it does not increase.

Note: This work has been performed under the direction of the Corps of Engineers. According to the Corps, it was effective in reducing the flows to an acceptable level.

3. Inspect the power tunnel periodically for overall stability of the tunnel. The enclosed geologic maps (Appendix B) of the excavations will provide a basis for evaluating any changes which may occur over time. The inspectors should be ready to recommend remedial treatment for specific reaches of the tunnels including scaling loose blocks, installing rock bolts, and applying shotcrete. All inspections should be made by an experienced geologist or geotechnical engineer accompanied by an experienced underground miner who could scale down any potentially unstable rock encountered in the excavations. The inspections should be performed 6 mo, 18 mo, 3 yr, and 5 yr after completion of the tunnel, and then every 5 yr throughout its period of use. The drawdown preceeding the inspections should be done slowly to avoid excessivec stresses on the tunnel.

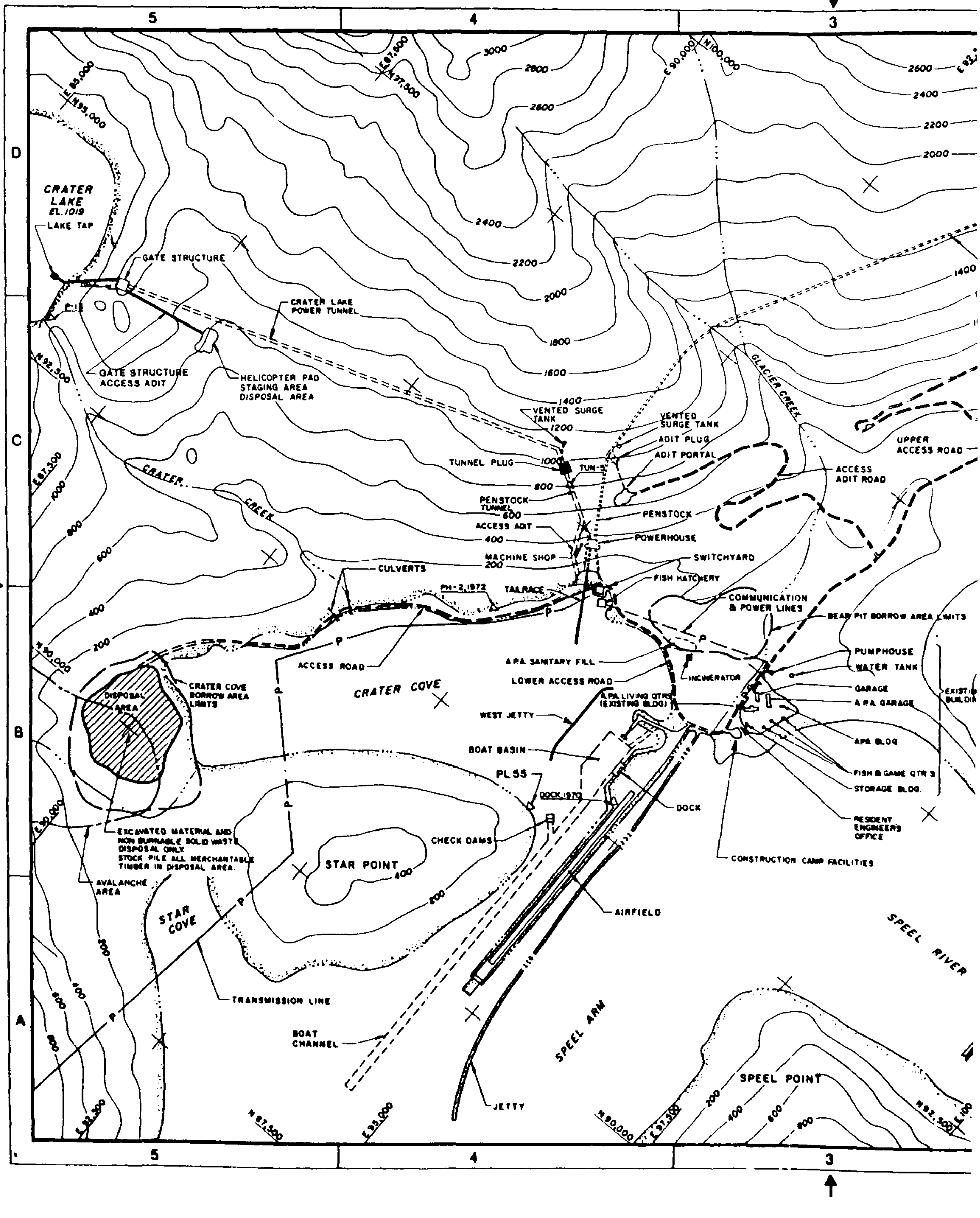
CLOSING STATEMENT

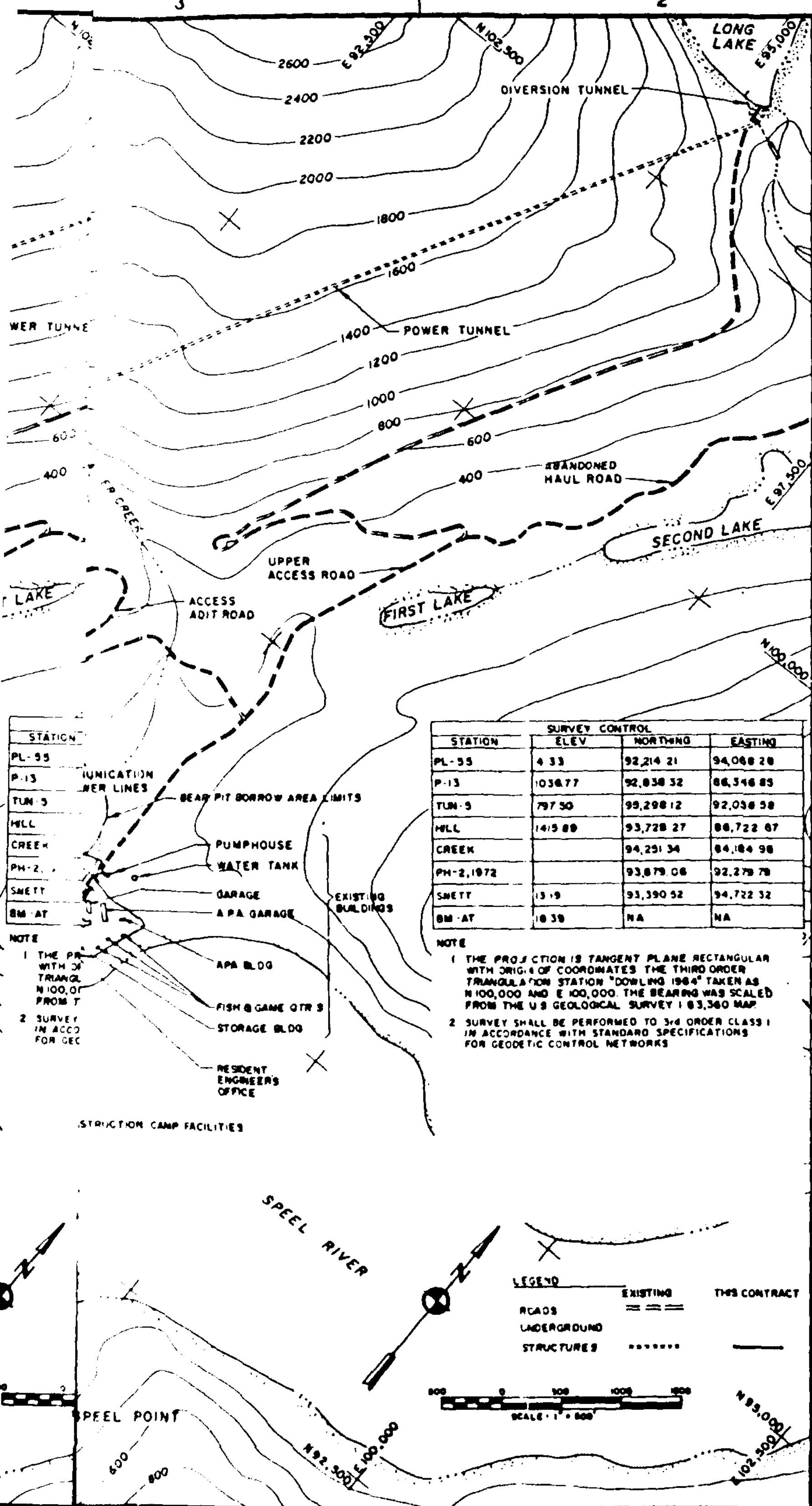
LACHEL & Associates, Inc. has been proud to be a part of this historic project. We are proud of the service provided to both the Alaska District, Corps of Engineers and the contractors and workers who successfully built the project. Overall cooperation between the various parties and individuals was good, and, most importantly, the safety of all participants was paramount in everyone's mind. Through more than 4 yrs and thousands of man-hours, there was not a single serious accident. This is a record that not only L&A, but everyone involved, should be proud of. We sincerely appreciate the opportunity to work on this project.

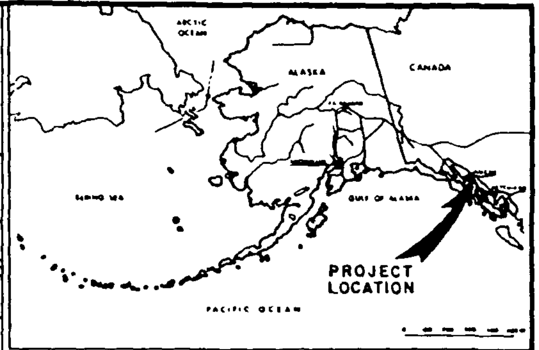
APPENDIX A

TEXT FIGURES

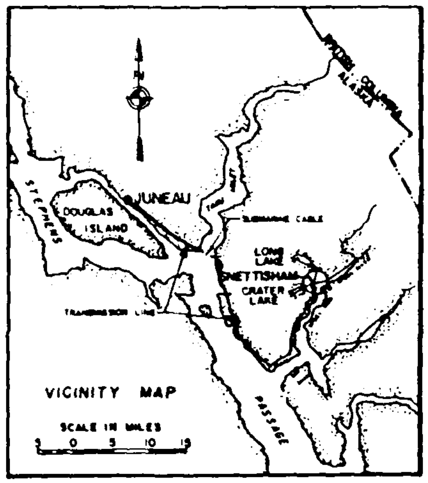
TEXT FIGURES


CRATER LAKE EL. 1019
LAKE TAP
GATE STRUCTURE
CRATER LAKE POWER TUNNEL
GATE STRUCTURE ACCESS ADIT
HELICOPTER PAD STAGING AREA DISPOSAL AREA
VENTED SURGE TANK
TUNNEL PLUG
PENSTOCK TUNNEL
ACCESS ADIT
MACHINE SHOP
ADIT PLUG
ADIT PORTAL
PENSTOCK
POWERHOUSE
SWITCHYARD
FISH HATCHERY
TAILRACE
CULVERTS
GLACIER CREEK
CRATER CREEK
ACCESS ADIT ROAD
UPPER ACCESS ROAD
COMMUNICATION & POWER LINES
BEAR PIT BORROW AREA LIMITS
PUMPHOUSE
WATER TANK
GARAGE
A.P.A. GARAGE
APA BLDG
FISH & GAME QTR 3
STORAGE BLDG.
RESIDENT ENGINEER'S OFFICE
CONSTRUCTION CAMP FACILITIES
A.P.A. SANITARY FILL
LOWER ACCESS ROAD
INCINERATOR
A.P.A. LIVING QTRS (EXISTING BLDG)
WEST JETTY
BOAT BASIN
DOCK
PL 55
DOCK 1970
CHECK DAMS
AIRFIELD
ACCESS ROAD
CRATER COVE
CRATER COVE BORROW AREA LIMITS
DISPOSAL AREA
EXCAVATED MATERIAL AND NON BURNABLE SOLID WASTE DISPOSAL ONLY. STOCK PILE ALL MERCHANTABLE TIMBER IN DISPOSAL AREA.
AVALANCHE AREA
STAR COVE
STAR POINT
TRANSMISSION LINE
BOAT CHANNEL
JETTY
SPEEL ARM
SPEEL POINT
SPEEL RIVER
PH-2,1972





LOCATION MAP



SURVEY CONTROL			
STATION	ELEV	NORTHING	EASTING
PL-55	4 33	92,214 21	94,068 28
P-13	1036.77	92,838 32	86,346 85
TUN-5	797 50	99,298 12	92,036 58
HILL	1415 89	93,728 27	86,722 67
CREEK		94,291 34	84,184 98
PH-2, 1972		93,879 06	92,279 78
SNETT	13 19	93,390 52	94,722 32
BM-AT	18 39	NA	NA

NOTE

1. THE PROJECTION IS TANGENT PLANE RECTANGULAR WITH ORIGIN OF COORDINATES THE THIRD ORDER TRIANGULATION STATION "DOWLING 1964" TAKEN AS N 100,000 AND E 100,000. THE BEARING WAS SCALED FROM THE U S GEOLOGICAL SURVEY 1 63,360 MAP.
2. SURVEY SHALL BE PERFORMED TO 3rd ORDER CLASS I IN ACCORDANCE WITH STANDARD SPECIFICATIONS FOR GEODETIC CONTROL NETWORKS

ELEVATIONS OF TIDE PLANES AT SPEEL RIVER REFERRED TO MEAN LOWER LOW WATER AND PROJECT DATUM ARE AS FOLLOWS:

	MLLW	PROJECT DATUM
HIGHEST TIDE (ESTIMATE)	22.5	11.4
MEAN HIGHER HIGH WATER	15.9	4 8
MEAN HIGH WATER	14.8	3.7
HALF TIDE LEVEL (MSL)	8 2	-2 9
MEAN LOW WATER	1.6	-9.5
MEAN LOWER LOW WATER	0.0	-11.1
LOWEST TIDE (ESTIMATE)	-5.7	-16 8
PROJECT DATUM	11.1	0.0

NOTE: ALL ELEVATIONS SHOWN ON THESE PLANS ARE WITH RESPECT TO PROJECT DATUM.

LEGEND

	EXISTING	THIS CONTRACT
ROADS		
UNDERGROUND STRUCTURES		

SCALE 1 : 500

CONTRACT NO DACW85-86-C-0019

CONTRACTOR PACIFIC VENTURES, INC.

CITY Bellevue STATE Washington

APPROVED Resident Engineer

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA

Designed by: JBL

Drawn by: GEK

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
MAIN CONTRACT CRATER LAKE

LOCATION AND VICINITY MAP
PROJECT GENERAL PLAN

SCALE AS SHOWN

DATE 86 Apr 21

AS-BLT.

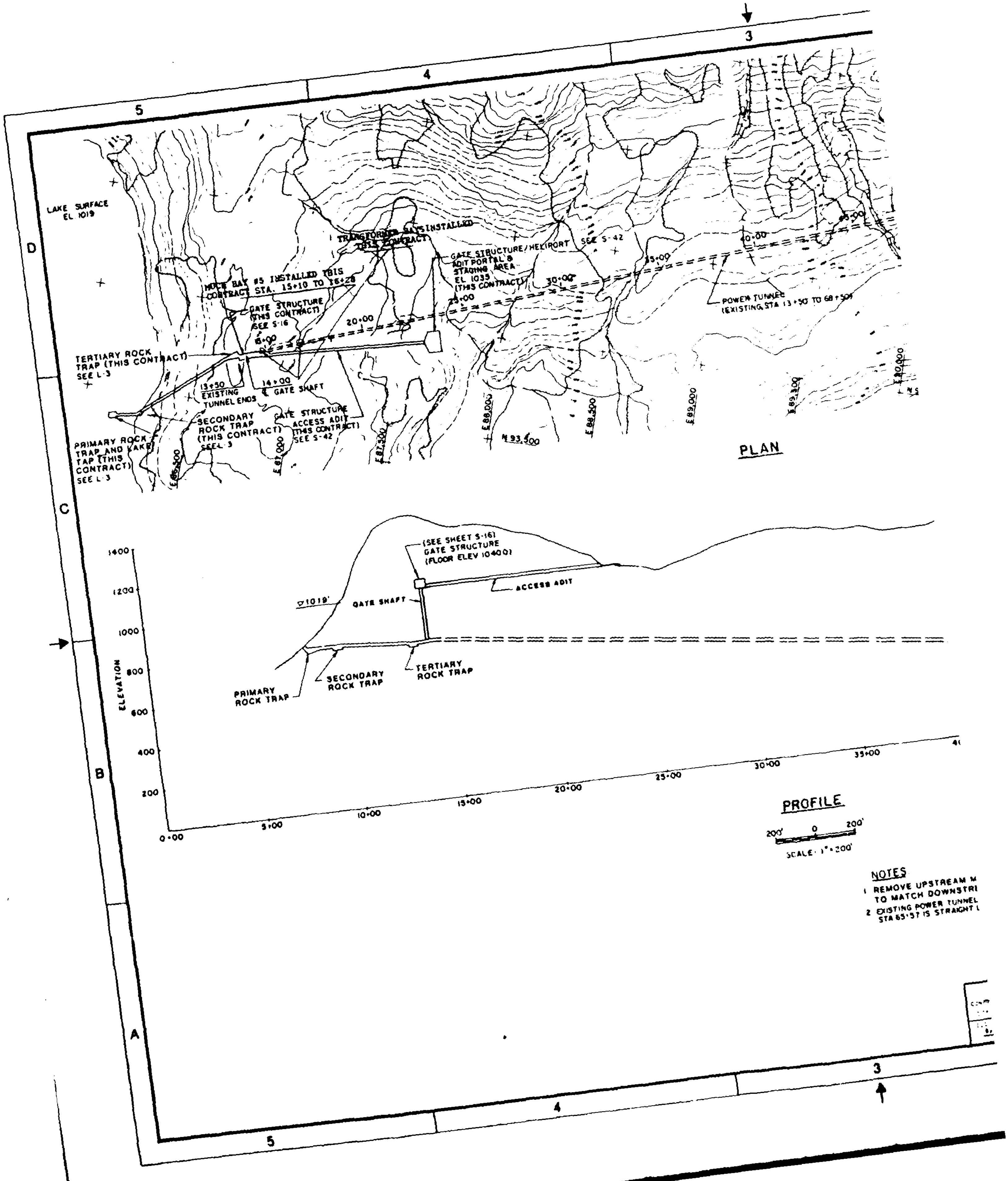
Drawing 1-SNE-86-06-

Sheet 2 of 252

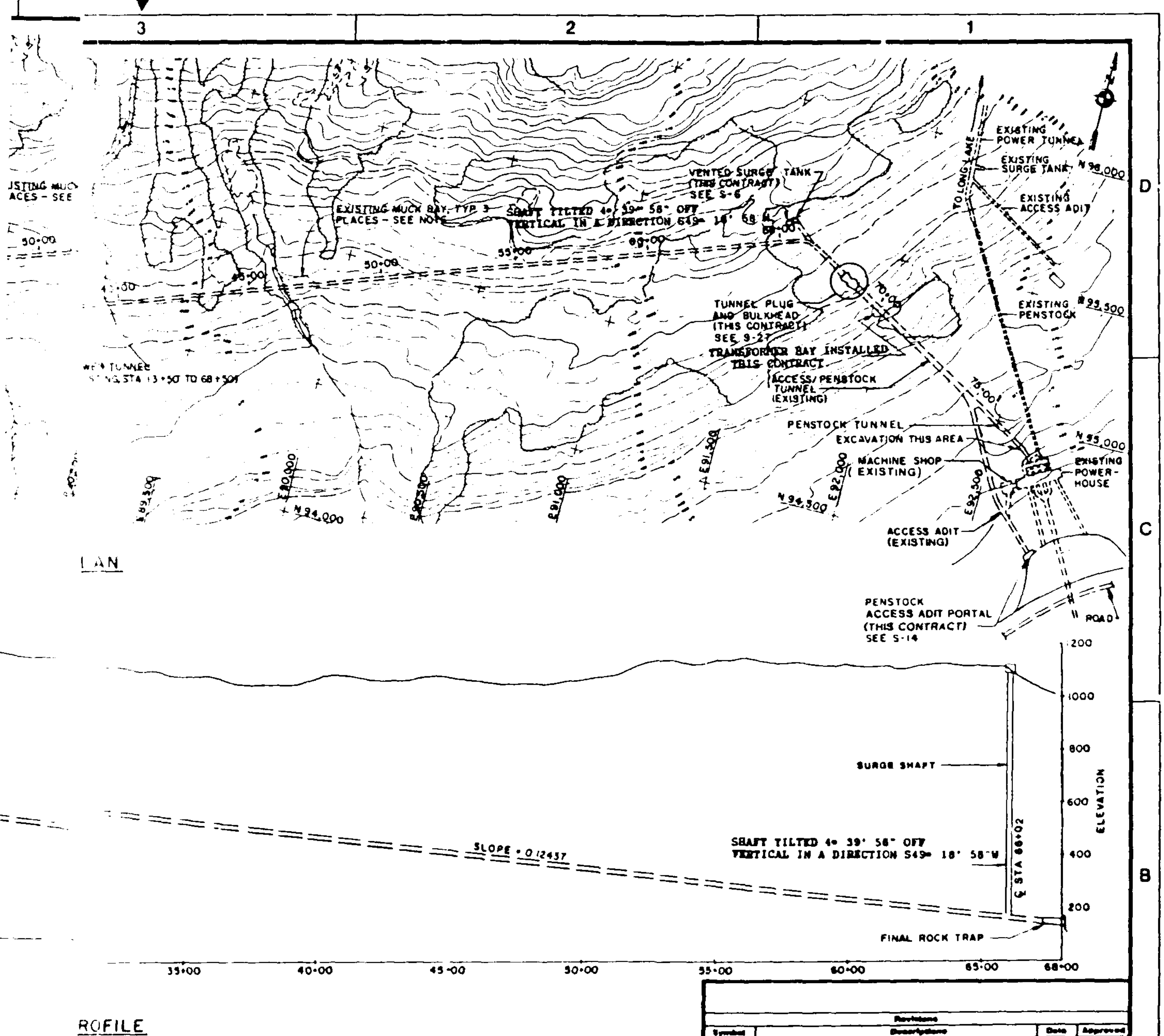
INV. NO. DACW 85-86-B-0002

FIGURE A-1

LACHEL & ASSOCIATES
GOLDEN, COLORADO



LAKE SURFACE EL 1019
TRANSFORMER BAYS INSTALLED THIS CONTRACT
GATE STRUCTURE/HELIPORT ADIT PORTAL & STAGING AREA EL 1035 (THIS CONTRACT)
SEE S-42
HOOD BAY #5 INSTALLED THIS CONTRACT STA. 15+10 TO 16+28
GATE STRUCTURE (THIS CONTRACT) SEE S-16
POWER TUNNEL (EXISTING STA 13+50 TO 68+50)
TERTIARY ROCK TRAP (THIS CONTRACT) SEE L-3
13+50 EXISTING TUNNEL ENDS
14+00 ℄ GATE SHAFT
GATE STRUCTURE ACCESS ADIT (THIS CONTRACT) SEE S-42
SECONDARY ROCK TRAP (THIS CONTRACT) SEE L-3
PRIMARY ROCK TRAP AND LAKE TAP (THIS CONTRACT) SEE L-3
15+00
20+00
25+00
30+00
35+00
40+00
45+00
E 85,500
E 87,000
E 87,500
E 88,000
N 93,500
E 88,500
E 89,000
E 89,500
E 90,000
PLAN
(SEE SHEET S-16) GATE STRUCTURE (FLOOR ELEV 1040.0)
ACCESS ADIT
▽1019'
GATE SHAFT
ELEVATION
1400
1200
1000
800
600
400
200
PRIMARY ROCK TRAP
SECONDARY ROCK TRAP
TERTIARY ROCK TRAP
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
PROFILE
200' 0 200'
SCALE: 1" = 200'
NOTES
1 REMOVE UPSTREAM M
TO MATCH DOWNSTR
2 EXISTING POWER TUNNEL
STA 65+57 IS STRAIGHT



0 200'
SCALE 1" = 200'

NOTES

1. REMOVE UPSTREAM MUCK BAY CORNERS TO MATCH DOWNSTREAM END
2. EXISTING POWER TUNNEL FROM STA 63+49 TO STA 65+57.15 STRAIGHT LEG HORSESHOE

LEGEND:

- - - EXISTING
——— NEW THIS CONTRACT

Symbol	Revisions Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

Designed by: JBL
Drawn by: GEK/JKL
Checked by:
Reviewed by:
Submitted by:

US Army Corps of Engineers

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE MAIN CONTRACT

POWER TUNNEL PLAN & PROFILE

Scale: 1" = 200'
Date: 26 Apr 87
Drawing Code: 1-SNE-98-08 -18-05/2
Sheet reference number: S-2
AS BLT
Sheet 139 of 232

CONTRACT NO DACW85-88-C-0019
CONTRACTOR PACIFIC VENTURES, INC.
State Washington
Approved
Resident Engineer
Date

INV. NO. DACW 85-86-B-0002

LACHEL & ASSOCIATES

FIGURE A-2

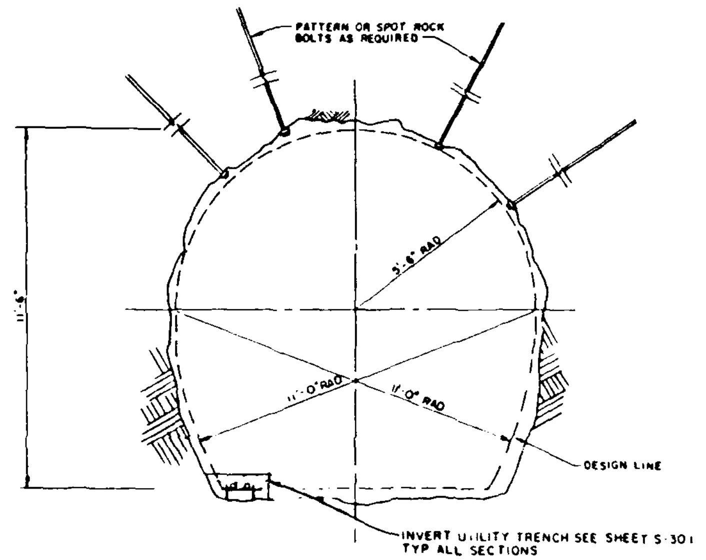
5 4 3

D

C

B

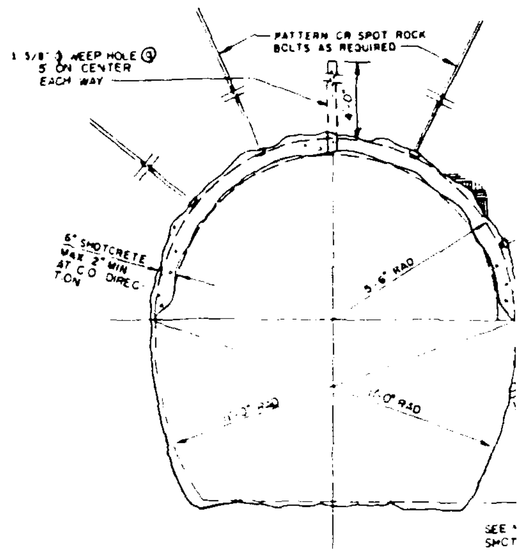
A



TYPICAL UNLINED SECTION

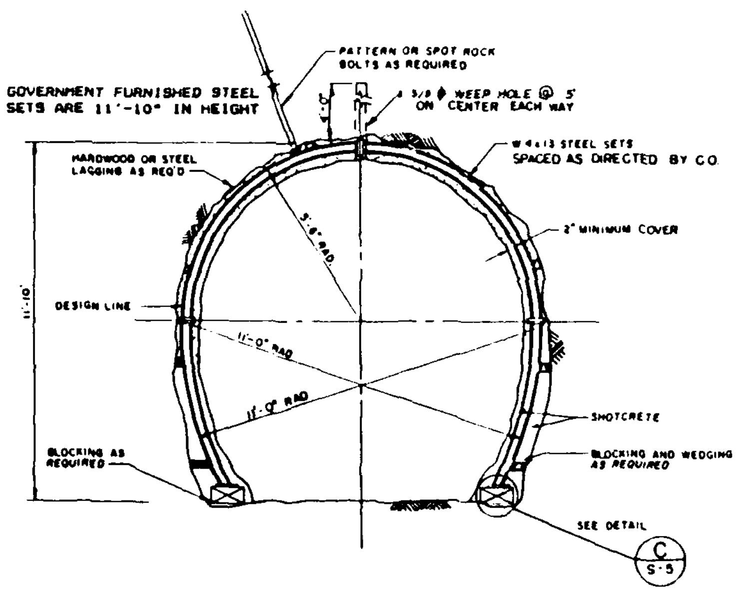
SCALE: 1/2"=1'-0"

TRANSITION TO STRAIGHT LEG
STA. 12+20 TO 12+50



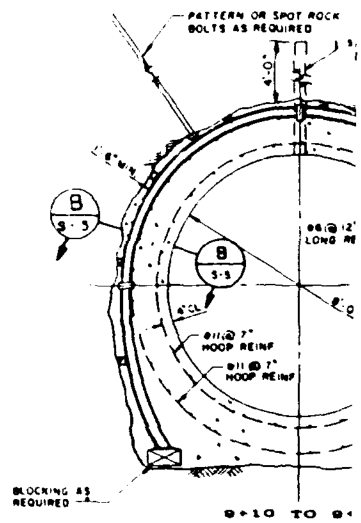
TYPICAL SHOTCRETE SECTION

SCALE: 1/2"=1'-0"



TYPICAL SET SUPPORTED SECTION

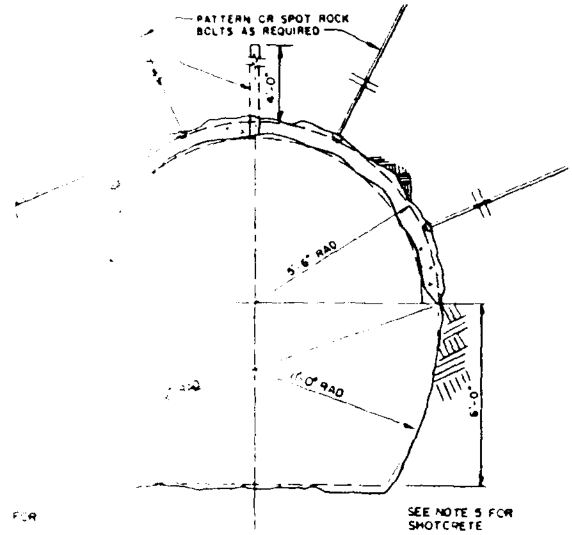
SCALE: 1/2"=1'-0"



SET SUPPORTED WITH C

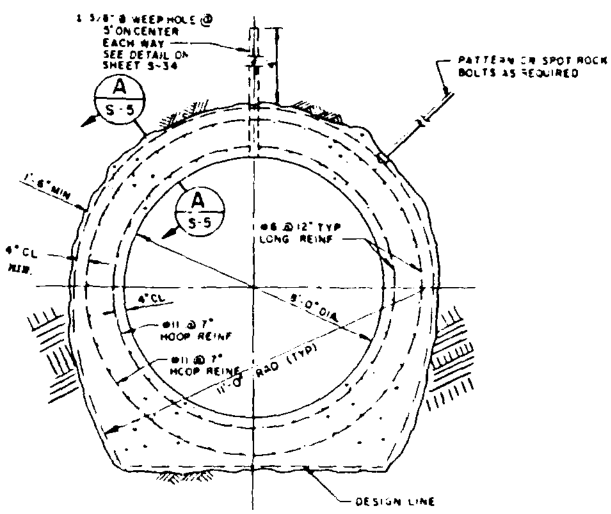
SCALE: 1/2"=1'-0"

5 4 3



ICAL SHOTCRETE SECTION

SCALE: 1/2"=1'-0"



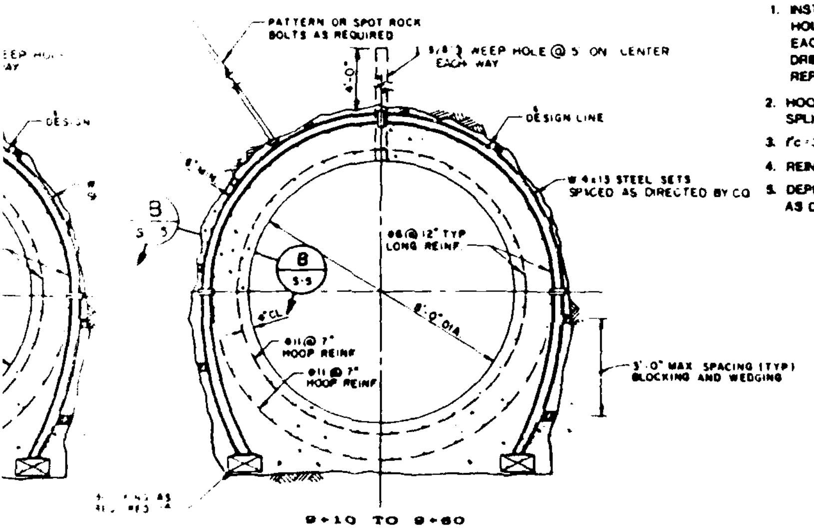
CONCRETE SUPPORTED

SCALE: 1/2"=1'-0"

9+60 TO 10+29

NOTES

1. INSTALL DRAIN HOLES THROUGH COMPLETED SHOTCRETE OR CONCRETE TUNNEL SUPPORT. HOLES SHALL BE 1⅝" NOMINAL DIAMETER, 4 FEET DEEP INTO ROCK, 5 FOOT CENTERS EACH WAY. IN VERY WET OR FRACTURED AREAS, INTERMEDIATE DRAIN HOLES SHALL BE DRILLED ABOVE SPRING LINE AS DIRECTED BY THE CONTRACTING OFFICER'S REPRESENTATIVE.
2. HOOP REINFORCEMENT SPLICES SHALL BE LAPPED A MINIMUM OF 5'-9". STAGGER HOOP SPLICES 30° BETWEEN ADJACENT BARS AND ADJACENT LAYERS.
3. f'c = 3000 PSI AT 28 DAYS.
4. REINFORCING STEEL SHALL BE GRADE 60.
5. DEPENDING ON ROCK CONDITIONS, SHOTCRETE MAY BE REQUIRED ON THE FLOOR INVERT AS DIRECTED BY THE C.O.



9+10 TO 9+60

SET SUPPORTED WITH CONCRETE LINING

SCALE: 1/2"=1'-0"

SCALE: 1/2"=1'-0"

Revisions			
Symbol	Descriptions	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE MAIN CONTRACT

POWER TUNNEL SECTIONS

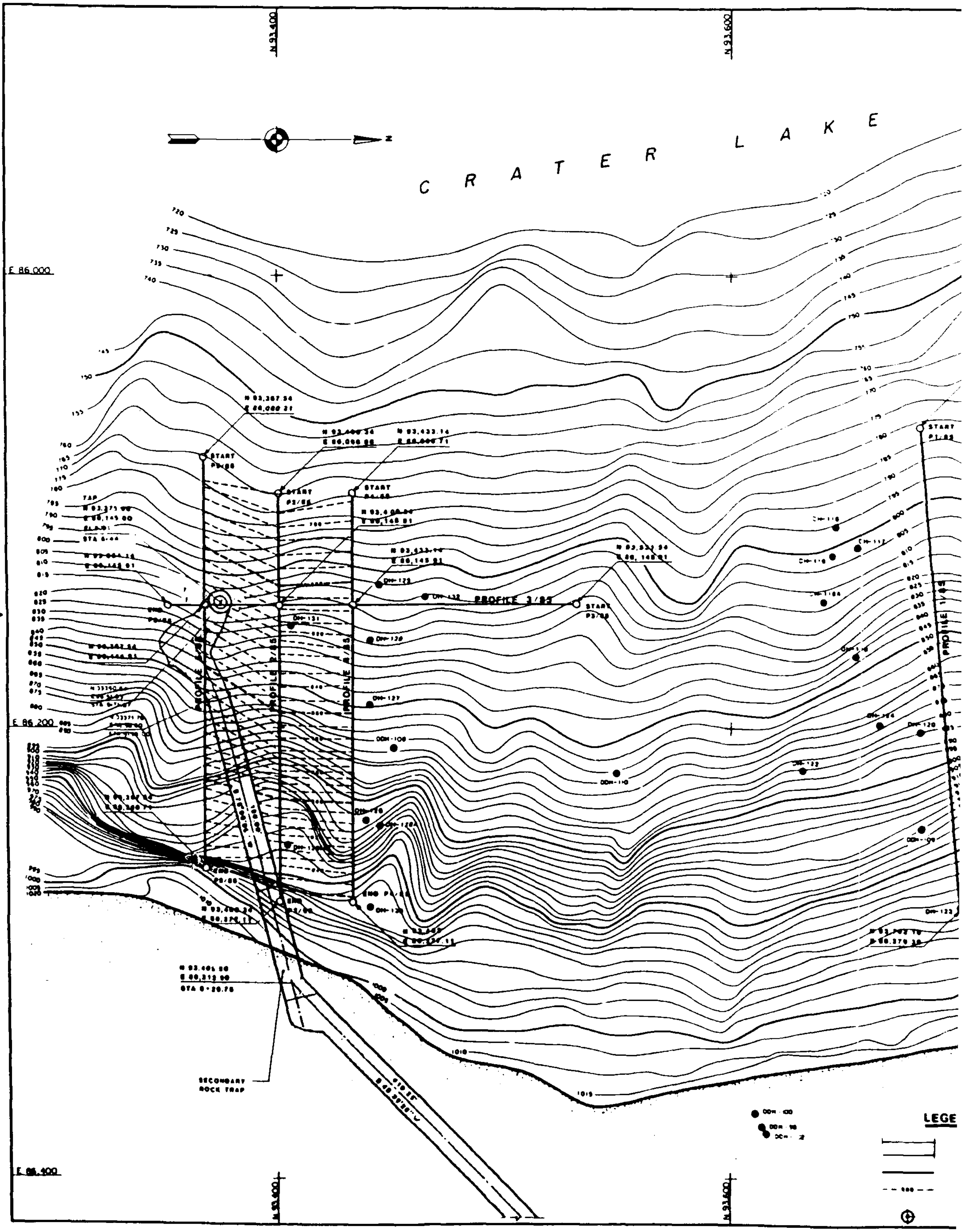
Designed by: JBL
Drawn by: TEB
Date: 86 Apr 21
Sheet reference number: S-4
AS-BLT
Sheet 141 of 252

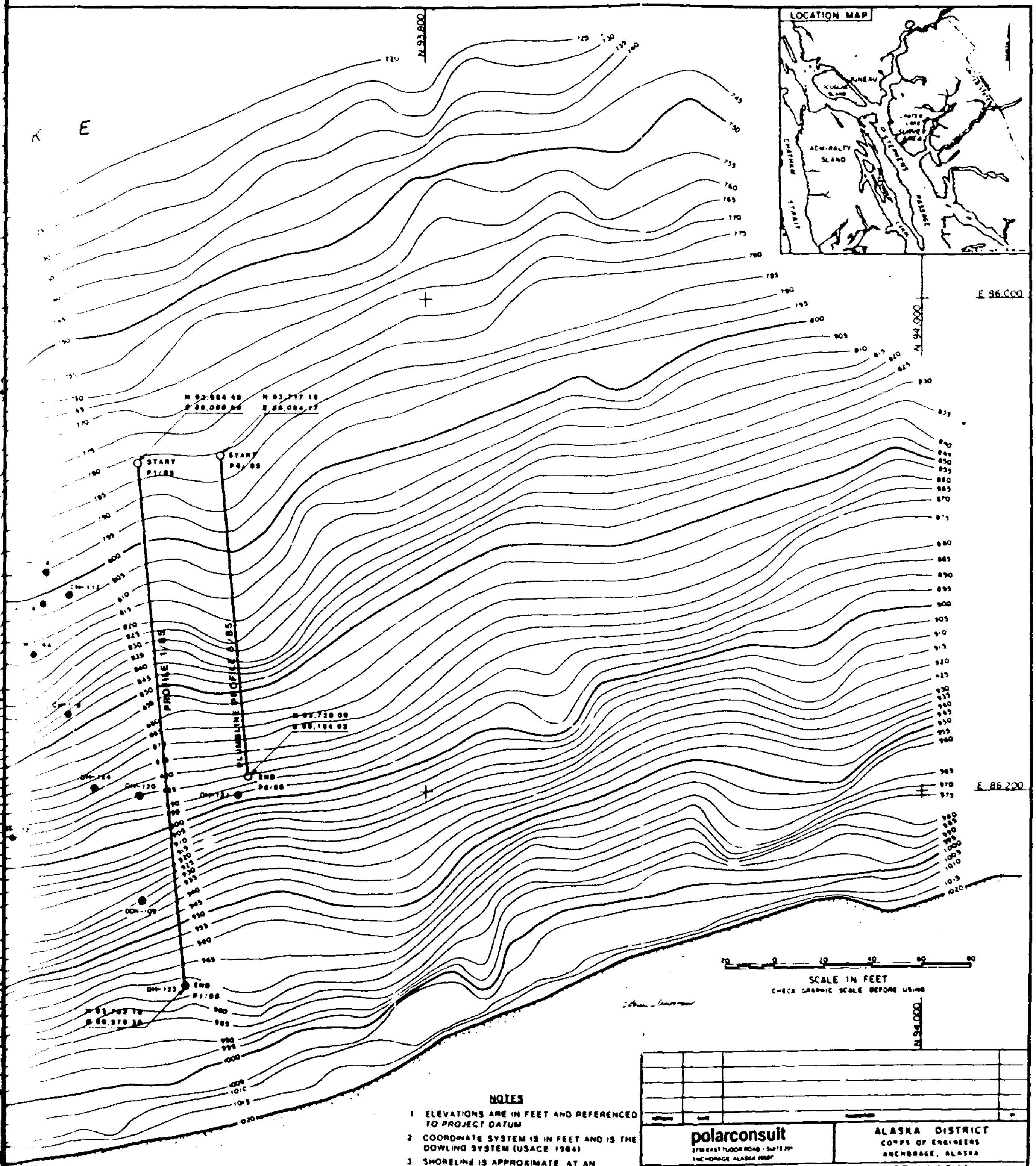
INV. NO. DACW 85-86-B-0002

FIGURE A-3

LACHEL & ASSOCIATES
GOLDEN, COLORADO

CORPS OF ENGINEERS





LEGEND:

PLANNED POWER TUNNEL

PROFILE LINES

CONTOUR LINES AT 5' INTERVALS

PROPOSED LAKE TAP LOCATION

NOTES

1. ELEVATIONS ARE IN FEET AND REFERENCED TO PROJECT DATUM
2. COORDINATE SYSTEM IS IN FEET AND IS THE DOWLING SYSTEM (USACE 1984)
3. SHORELINE IS APPROXIMATE, AT AN ELEVATION OF 1020 FEET ABOVE MSL AND WAS PLOTTED FROM SIDE SCAN SONAR DATA
4. DRILL HOLE CORE LOGS ARE INCLUDED IN THE SPECIFICATIONS
5. FOR PROFILE LINES SEE U.S. ARMY CORPS "REFRACTION SEISMIC SURVEY AND LAKE TAP REPORT" OF MARCH 1985

polarconsult

ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

Designed by: FR
Checked by: JT

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE MAIN CONTRACT

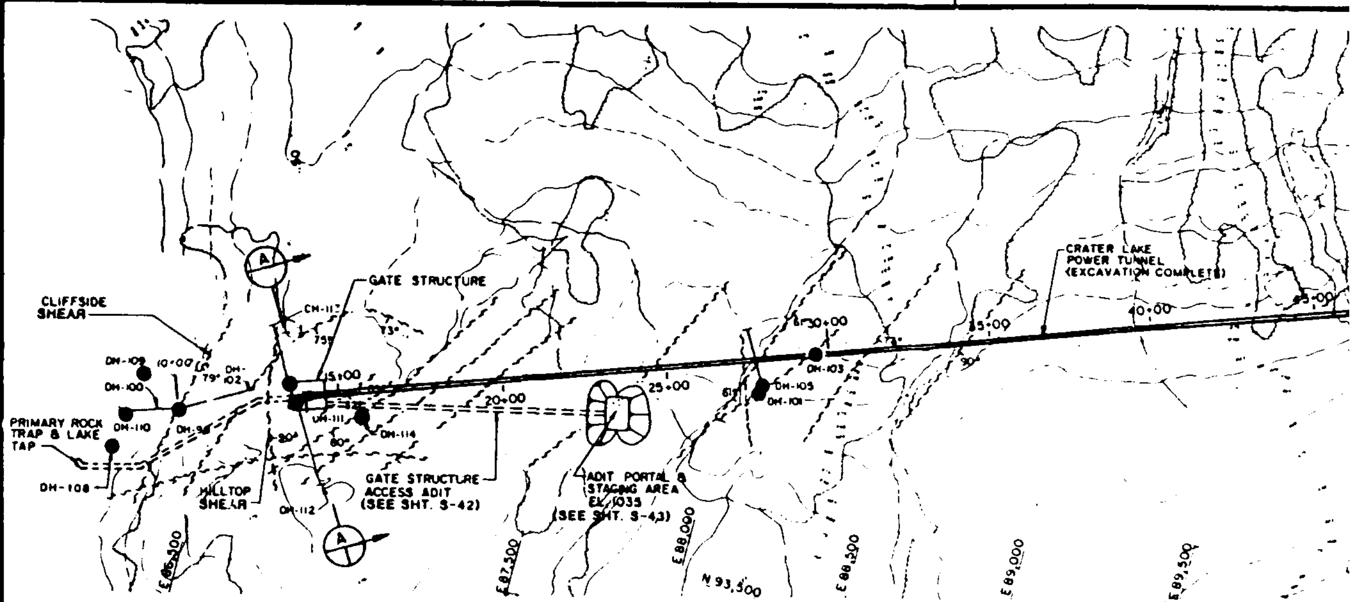
BEDROCK ELEVATIONS AND LAKE TAP TUNNEL ALIGNMENT

SCALE 1" = 20'
L-1
197 OF 292

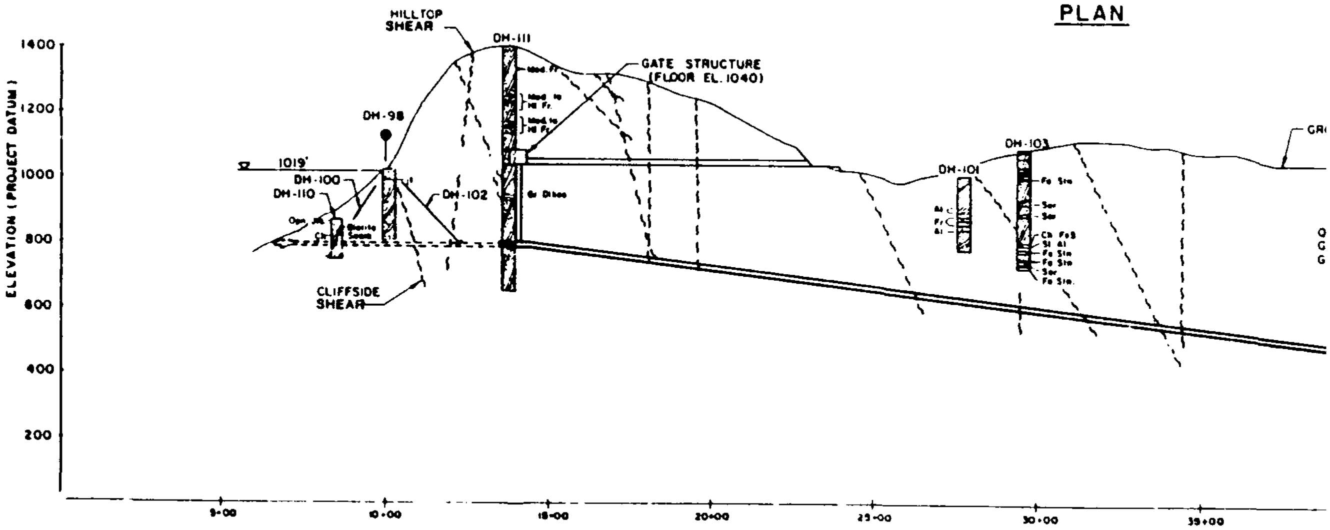
INV. NO. DACW 85-86-B-0002 AS-BLT

FIGURE A-4

LACHEL & ASSOCIATES



PLAN



PROFILE

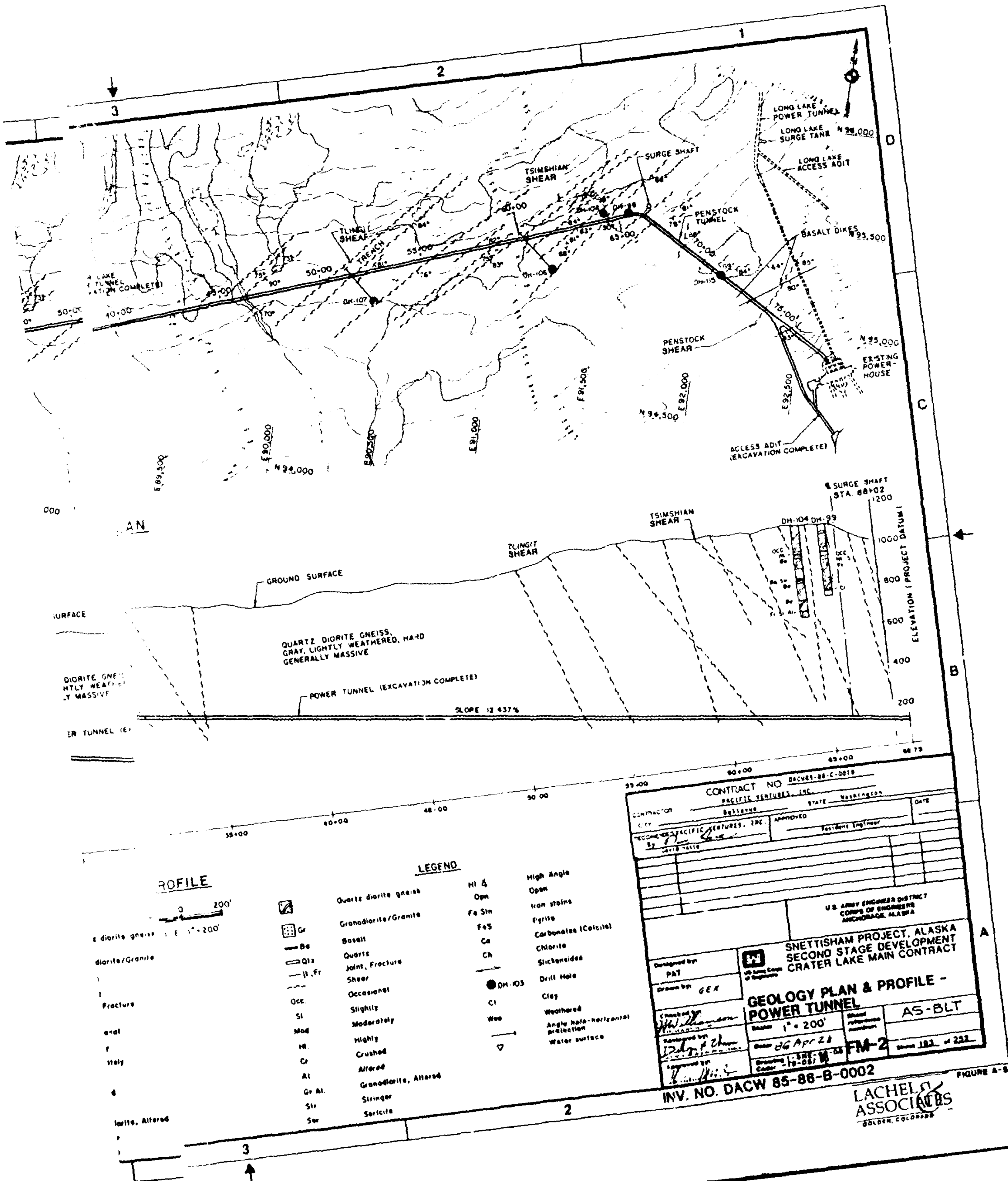
200' 0 200'

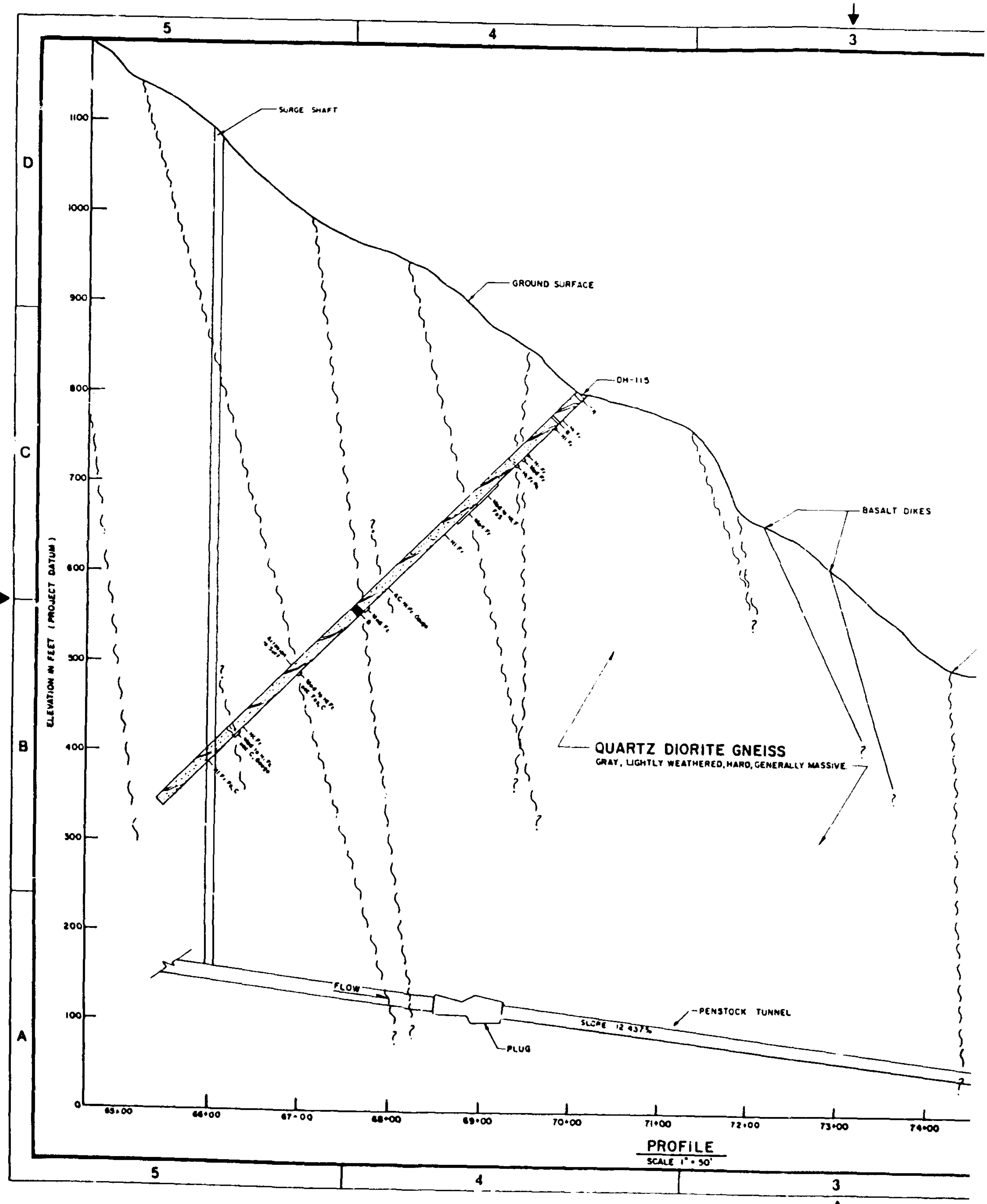
SCALE 1" = 200'

NOTES:

1. TUNNEL/SHEAR INTERCEPTS ARE STRAIGHT LINE PROJECTIONS OF APPARENT DIPS. DIPS NORMALLY VARY. PROJECTIONS ILLUSTRATE THE LIKELIHOOD OF AN INTERSECTION AT TUNNEL ELEVATIONS. EXACT LOCATION OF INTERSECTIONS CANNOT BE GUARANTEED.
2. SEE SHEET L-1 FOR LAKE EXPLORATIONS.
3. SEE SPECIFICATIONS FOR LOGS OF EXPLORATIONS.
4. THIS DRAWING IS TO BE USED TO SHOW ONLY THE GEOLOGY AND EXPLORATIONS IN THE AREA. SEE APPLICABLE DRAWINGS FOR EXISTING AND NEW FACILITIES.

Gr
Ba
Qtz
Jt, Fr
Occ.
Sl
Mod
Hi.
Cr.
Al
Gr Al.
Str
Ser


LONG LAKE POWER TUNNEL
LONG LAKE SURGE TANK
LONG LAKE ACCESS ADIT
SURGE SHAFT
TSIMSHIAN SHEAR
TLINGIT SHEAR
TRENCH
PENSTOCK TUNNEL
BASALT DIKES
PENSTOCK SHEAR
EXISTING POWER-HOUSE
ACCESS ADIT (EXCAVATION COMPLETE)
DH-107
DH-105
DH-115
N 96,000
N 95,500
N 95,000
N 94,500
N 94,000
E 89,500
E 90,000
E 90,500
E 91,000
E 91,500
E 92,000
E 92,500
GROUND SURFACE
QUARTZ DIORITE GNEISS, GRAY, LIGHTLY WEATHERED, HARD GENERALLY MASSIVE
POWER TUNNEL (EXCAVATION COMPLETE)
SLOPE 12.437%
℄ SURGE SHAFT STA. 68+02
DH-104
DH-99
ELEVATION (PROJECT DATUM)
PROFILE
LEGEND
Quartz diorite gneiss
Granodiorite/Granite
Basalt
Quartz
Joint, Fracture
Shear
Occasional
Slightly
Moderately
Highly
Crushed
Altered
Granodiorite, Altered
Stringer
Sericite
High Angle
Open
Iron stains
Pyrite
Carbonates (Calcite)
Chlorite
Slickensides
Drill Hole
Clay
Weathered
Angle hole-horizontal projection
Water surface
CONTRACT NO DACW85-88-C-0019
CONTRACTOR PACIFIC VENTURES, INC.
CITY Bellevue
STATE Washington
APPROVED
Resident Engineer
DATE
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE MAIN CONTRACT
Designed by: PAT
Drawn by: GEK
GEOLOGY PLAN & PROFILE - POWER TUNNEL
Scale 1" = 200'
AS-BLT
FM-2
Sheet 183 of 232
INV. NO. DACW 85-88-B-0002
FIGURE A-5
LACHEL & ASSOCIATES
GOLDEN, COLORADO



PROFILE

SCALE 1" = 50'

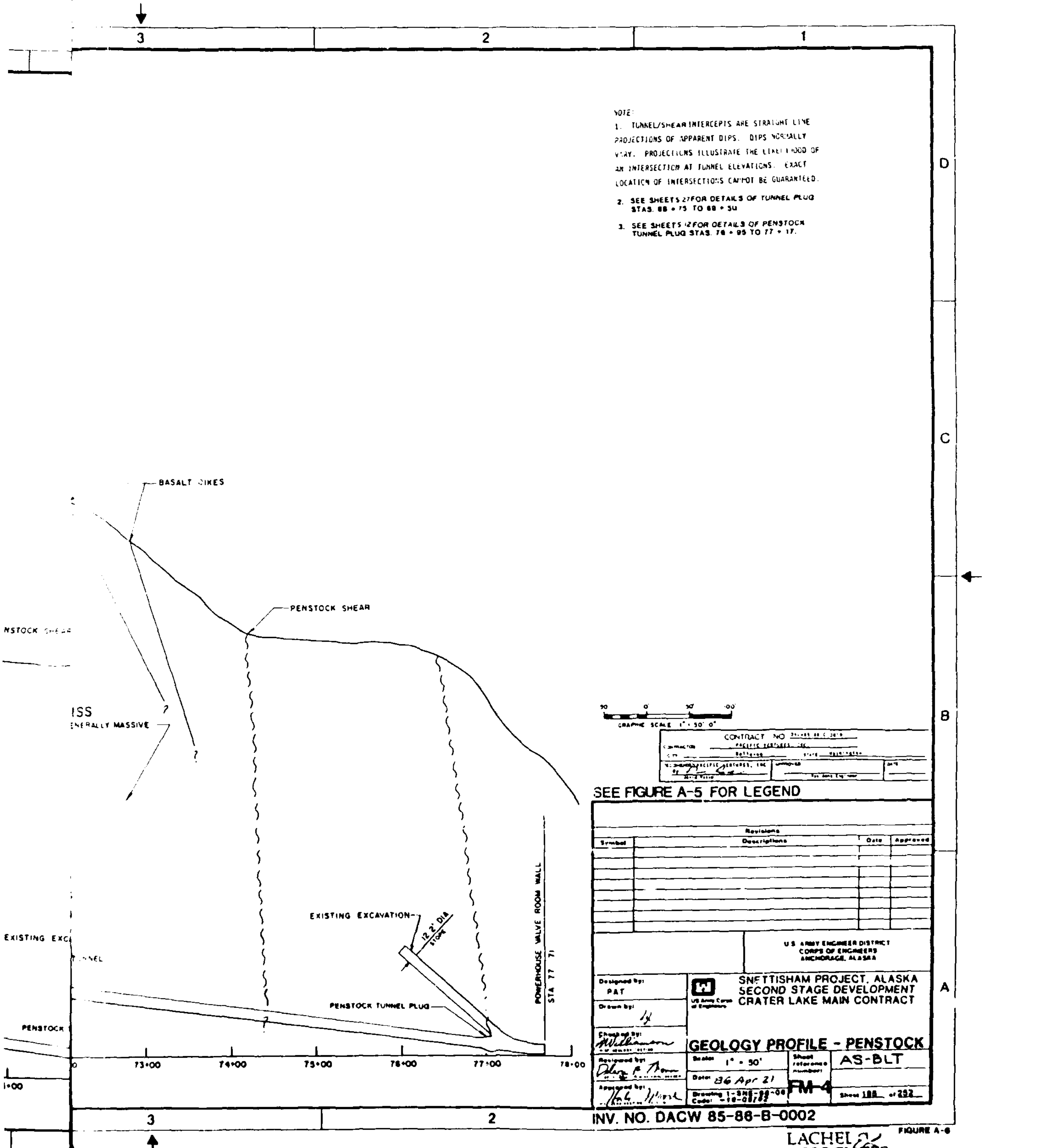
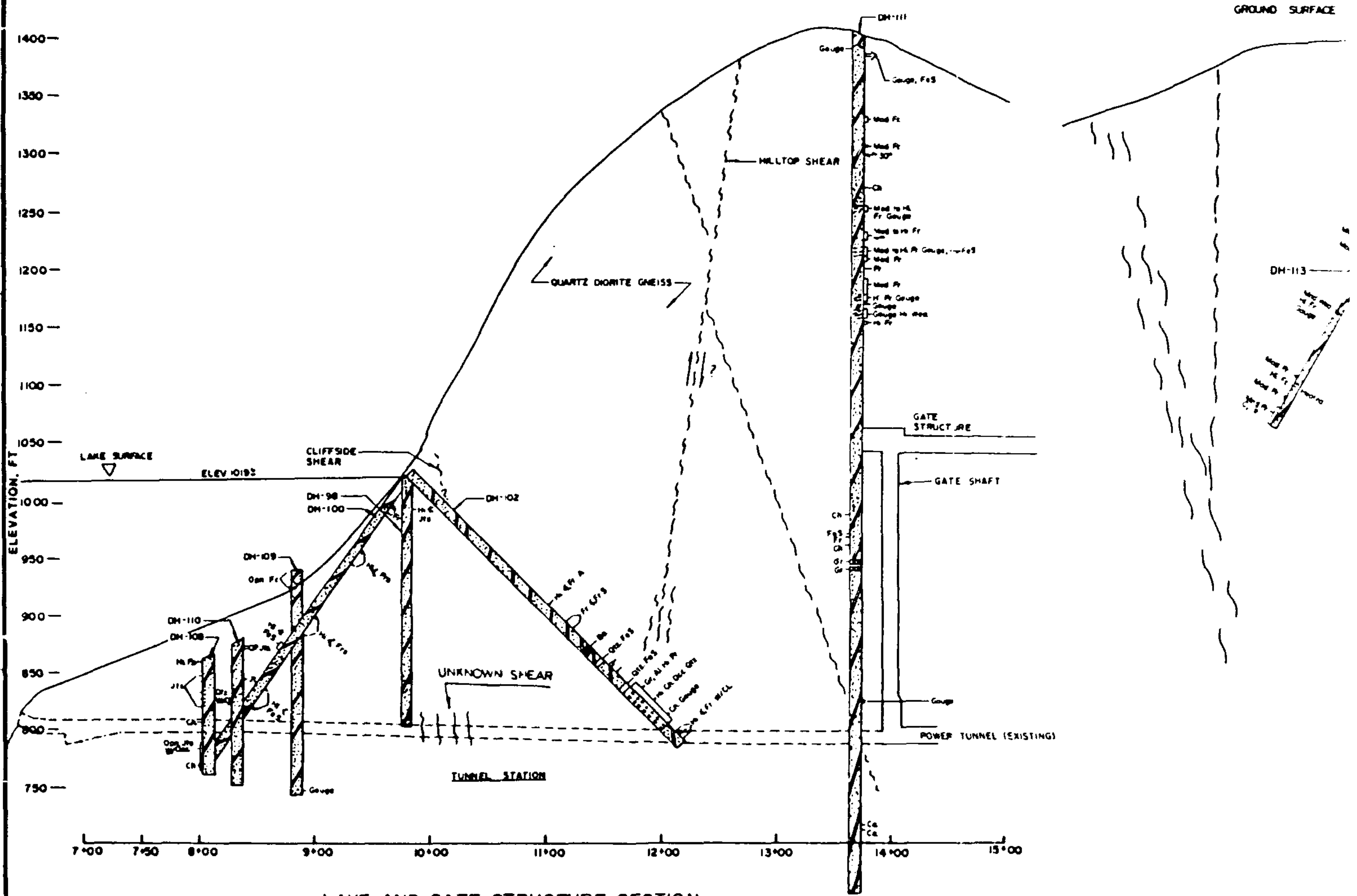


FIGURE A-6

LACHEL & ASSOCIATES
GOLDEN, COLORADO



LAKE AND GATE STRUCTURE SECTION

SCALE: 1" = 30'

NOTES:

1. THIS DRAWING SHOWS GEOLOGY AND EXPLORATIONS IN THE GATE STRUCTURE AND LAKE AREA. SEE APPLICABLE DRAWINGS FOR EXISTING AND NEW FACILITIES.
2. CORED PILOT HOLE, REQUIRED IN THE SPECIFICATIONS, IS INTENDED TO INTERCEPT THE HIGHLY FRACTURED AND ALTERED ZONE NEAR THE BOTTOM OF DH-102. ACTUAL STARTING STATION FOR THE PILOT HOLE WILL DEPEND ON CONDITIONS IN THE FIELD.
3. DH-98, -100, -102, -108, -109 AND -110 DO NOT CROSS THE PROPOSED TUNNEL ALIGNMENT.

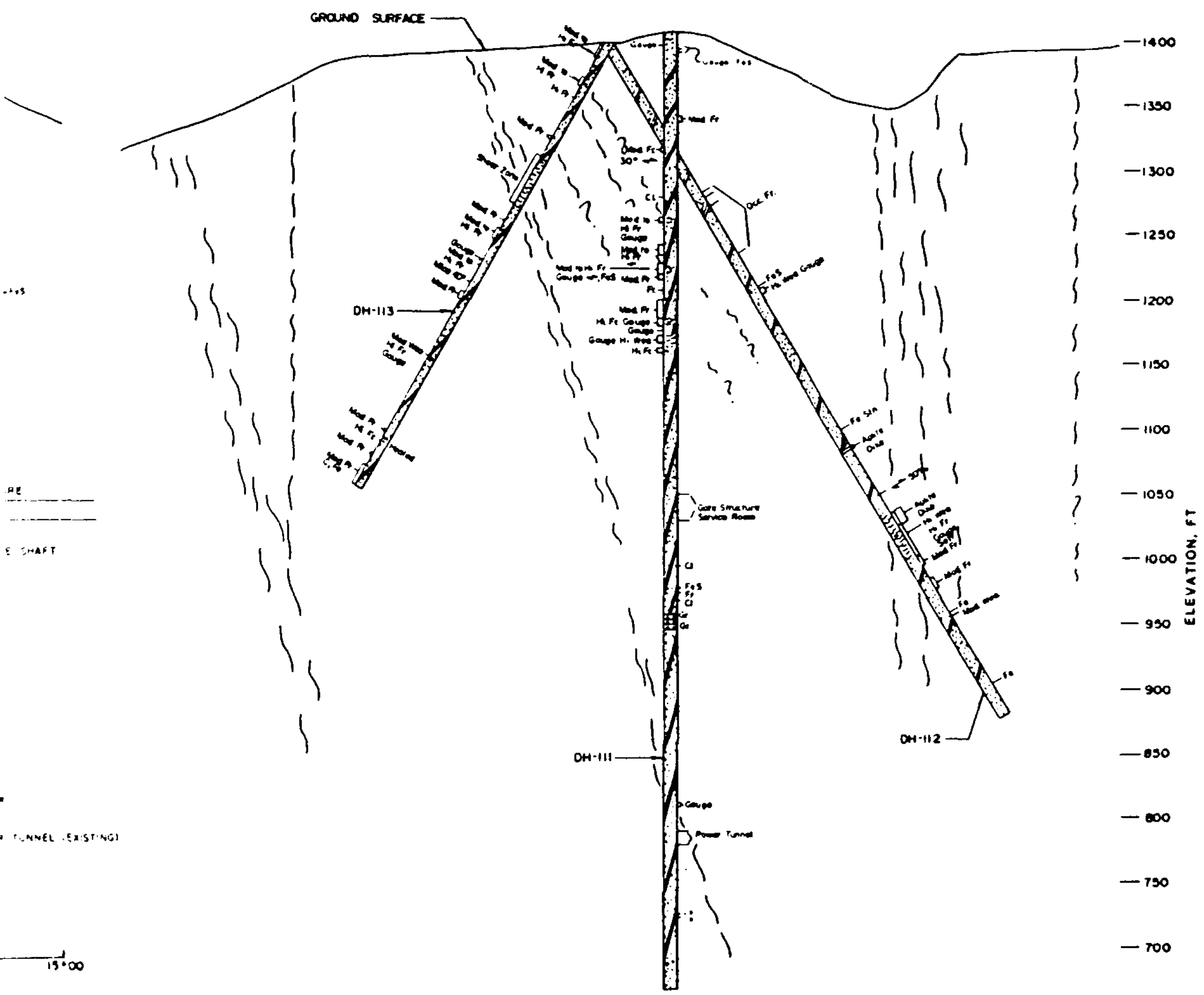
CONTRACT

CONTRACTOR PACIFIC V...

CITY Bellevue

RECOMMENDED PACIFIC VENTURES, INC

By



SECTION (A) FIG. A-8
SCALE 1" = 50'

SEE FIGURE A-5 FOR LEGEND

Revisions			
Symbol	Descriptions	Date	Approved

GRAPHIC SCALE: 1" = 50'-0"

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE MAIN CONTRACT

GEOLOGY SECTIONS
LAKE & GATE STRUCTURE

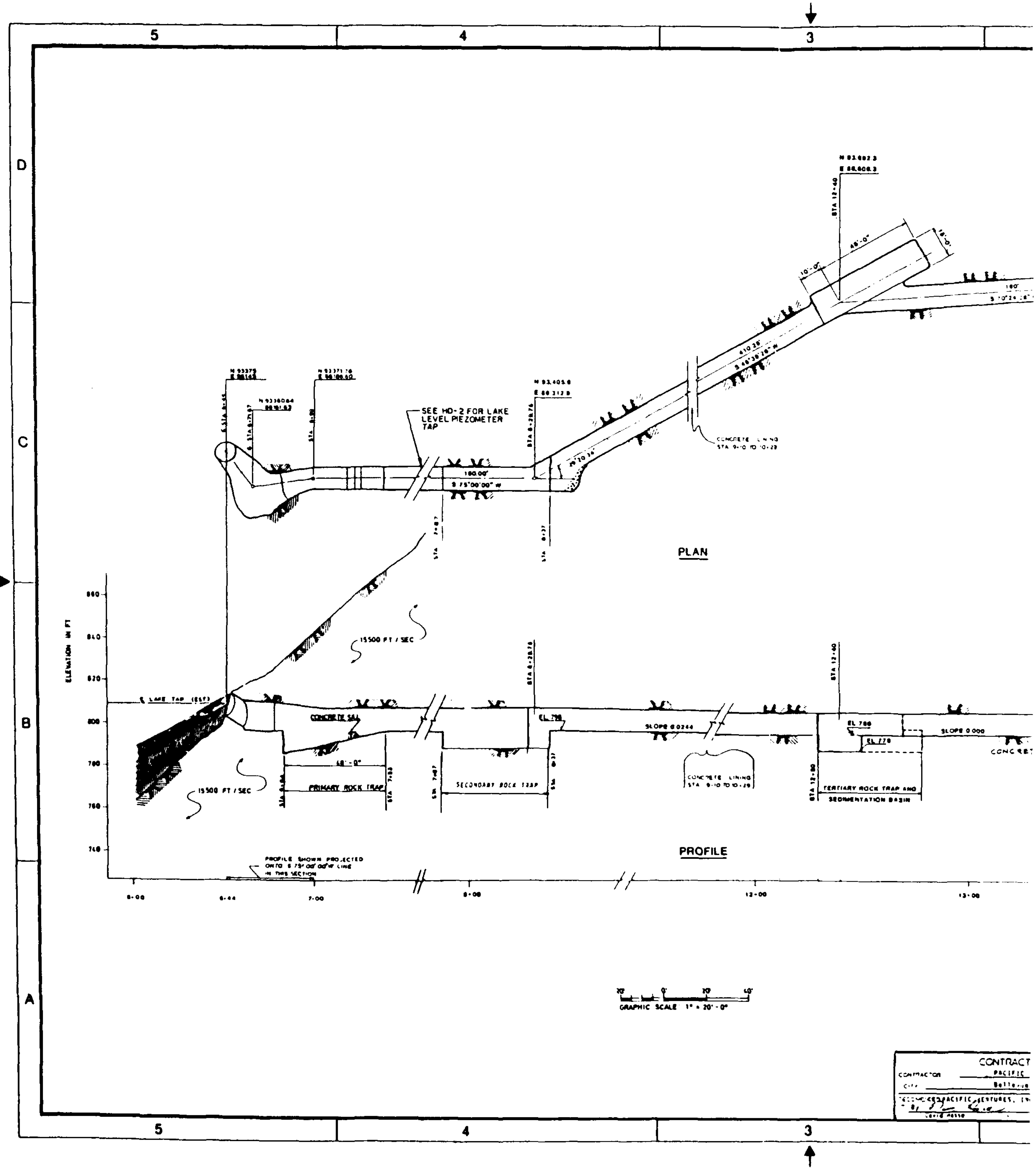
Designed by: PAT
Drawn by: CAK
Checked by: CH. GEOLOGY SECTION
Reviewed by: CH. F & S BRANCH
Approved by: CH. ENGR DIV
Scale: 1" = 50'
Date: 86 Apr 21
Drawing Code: 1-SNE-86-06 19-08/31
Sheet reference number: FM-3
AS-BLT
Sheet 194 of 292

CONTRACT NO DACW85-86-C-0019
CONTRACTOR PACIFIC VENTURES, INC.
CITY Bellevue STATE Washington
RECOMMENDED PACIFIC VENTURES, INC. David Hesse
APPROVED Resident Engineer
DATE

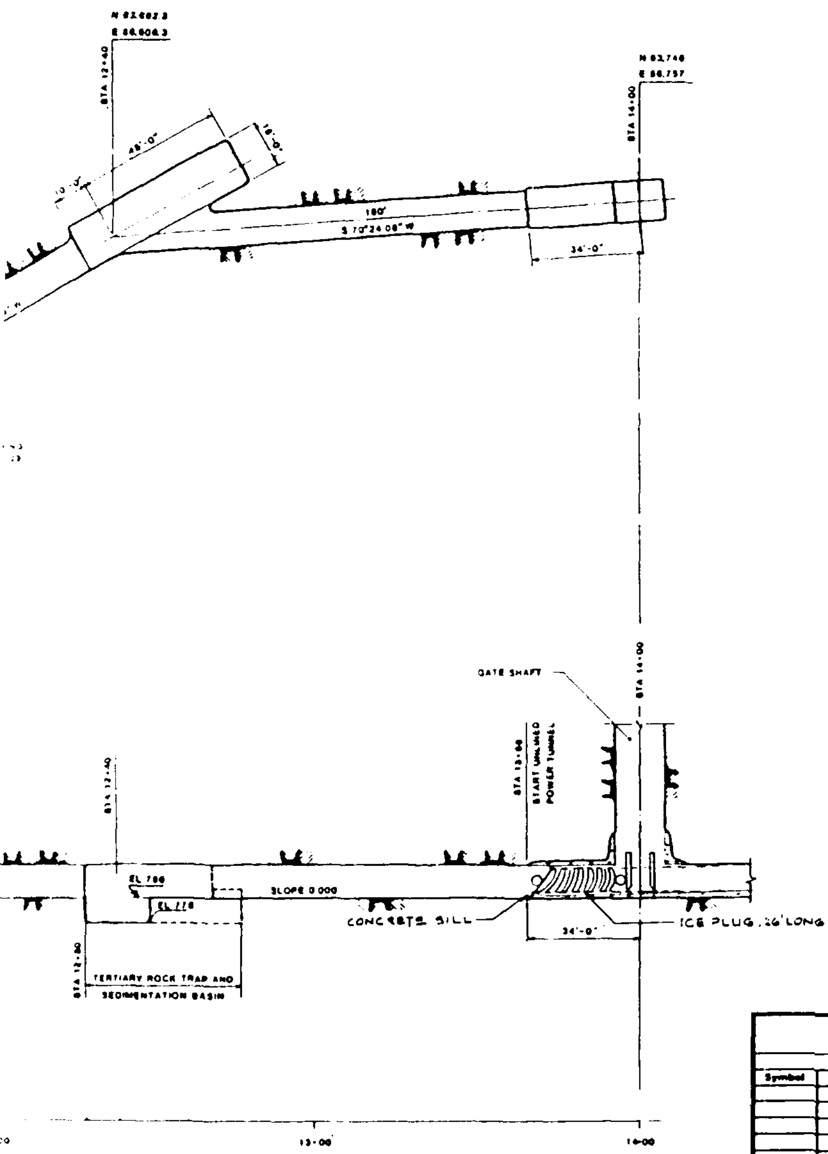
INV. NO. DACW 85-86-B-0002

FIGURE A-7

LACHEL & ASSOCIATES
GOLDEN, COLORADO



5
4
3
D
C
B
A
SEE HD-2 FOR LAKE LEVEL PIEZOMETER TAP
PLAN
PROFILE
ELEVATION IN FT
15500 FT / SEC
CONCRETE SILL
PRIMARY ROCK TRAP
SECONDARY ROCK TRAP
TERTIARY ROCK TRAP AND SEDIMENTATION BASIN
CONCRETE LINING STA 9+10 TO 10+29
PROFILE SHOWN PROJECTED ONTO S 75°00'00"W LINE IN THIS SECTION
GRAPHIC SCALE 1" = 20'-0"
CONTRACT



GENERAL NOTES

1. REFRACTION SEISMIC SURVEY OVERBURDEN AND ROCK VELOCITIES ARE SHOWN IN FT/SEC.
2. POWER TUNNEL AND ROCK TRAPS SHOULD GENERALLY BE UNLINED WITH CROSS SECTION AS SHOWN ON SHEET . PROVISIONS FOR LINING SECTIONS OF THE TUNNEL AND ROCK TRAPS HAVE BEEN PROVIDED FOR, SHOULD SUCH BE JUDGED NECESSARY BY THE CONTRACTING OFFICER.
3. CONCRETE SILL MAY BE CAST IN PLACE OR PRECAST, BEING TIED INTO THE ROCK WITH 1" ø × 8' ROCK BOLTS.

Revisions			
Symbol	Descriptions	Date	Approved

polarconsult

U S ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

US Army Corps of Engineers

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE MAIN CONTRACT

POWER TUNNEL PLAN AND PROFILES SHOWING ROCK TRAPS

Designed by:	FR
Checked by:	JT
Checked by:	[illegible]
Reviewed by:	Chief Branch
Approved by:	Chief Eng. Div.
Scale:	1" = 20'-0"
Date:	4-20-86
Drawing Code:	1-SNE-86-06-10-06/56
Sheet reference number:	L-2
	AS - BLT
Sheet	198 of 252

CONTRACT NO DACW85-86-C-0015
CONTRACTOR PACIFIC VENTURES, INC.
CITY Bellevue STATE Washington
PACIFIC VENTURES, INC.
APPROVED
Resident Engineer
DATE

INV. NO. DACW 85-86-B-0002

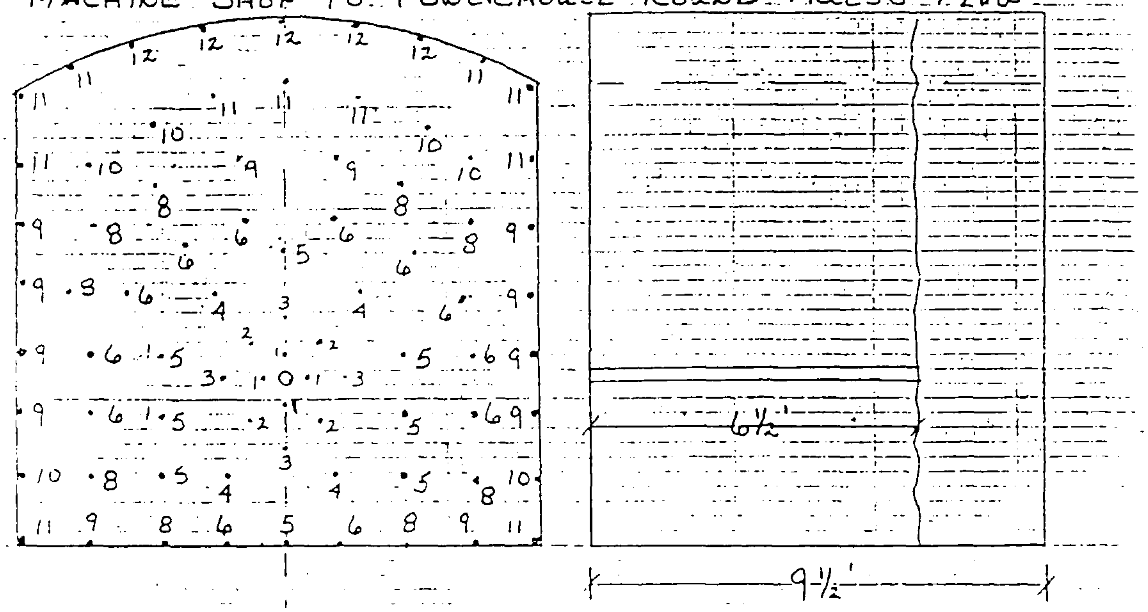
FIGURE A-8

LACHEL & ASSOCIATES
GOLDEN, COLORADO

PACIFIC VENTURES

CRATER LAKE
MAIN CONTRACT
DACW 85-86-C-0019

MACHINE SHOP TO POWERHOUSE ROUND - ACCESS PLUG



4" BURN HOLE 1 3/4' SHOT HOLES

ROUND WILL BE SHOT ONE DELAY AT A TIME USING 2-3 STICKS OF POWDER (TOVEX) PER HOLE. THIS WILL ASSURE THAT PARTICAL VELOCITY WILL REMAIN UNDER 2 IPS. (ATTACHED)

DUST CONTROL WILL BE DONE WITH A WOOD FRAME, VISQUENE SEALANT AND PLYWOOD ON THE POWER HOUSE SIDE

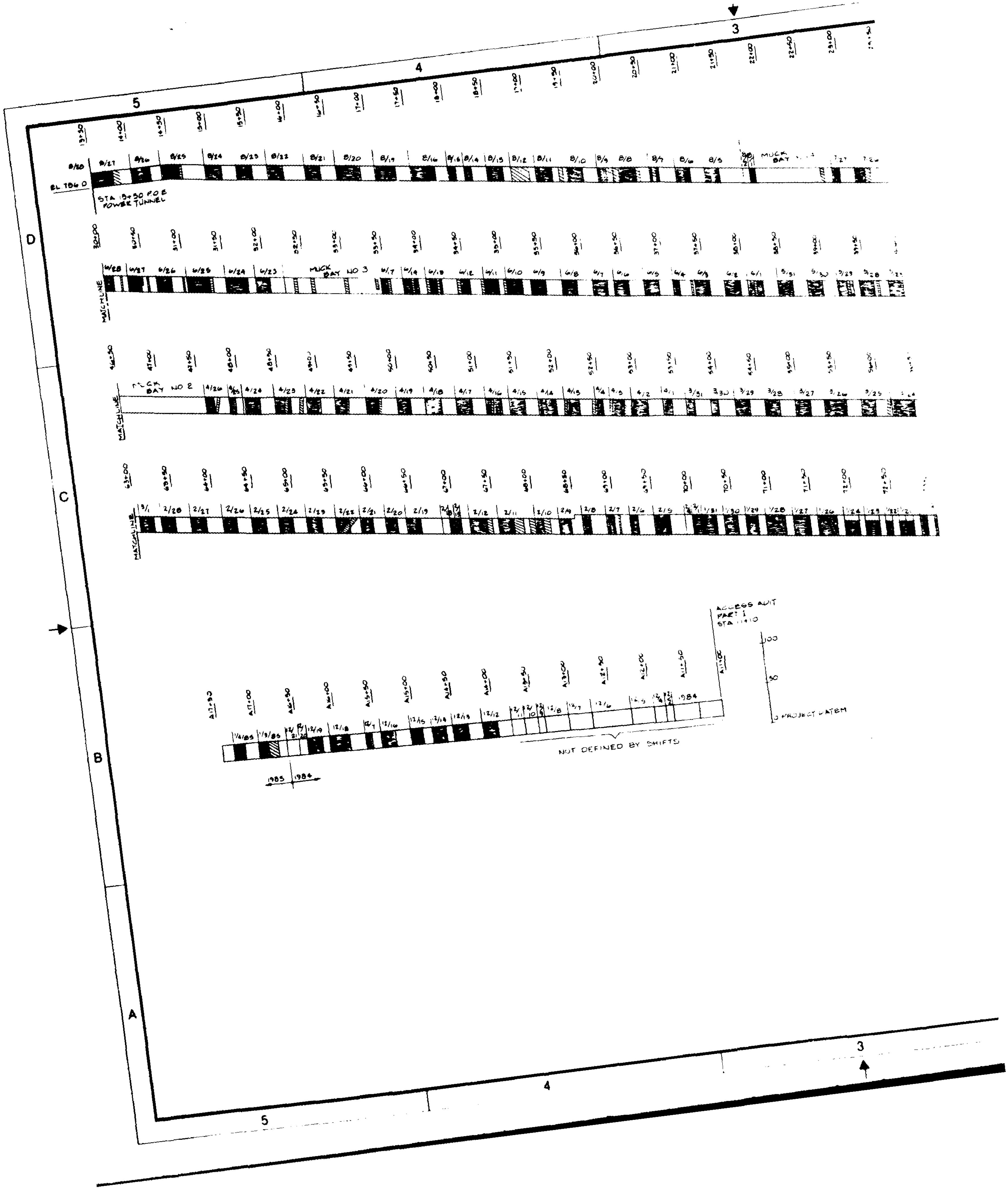
THE FINAL PLUG WILL BE BROKEN OUT USING A 3" DRILL PATTERN REAMED OUT TO 5" AND BROKEN OUT BY HAND

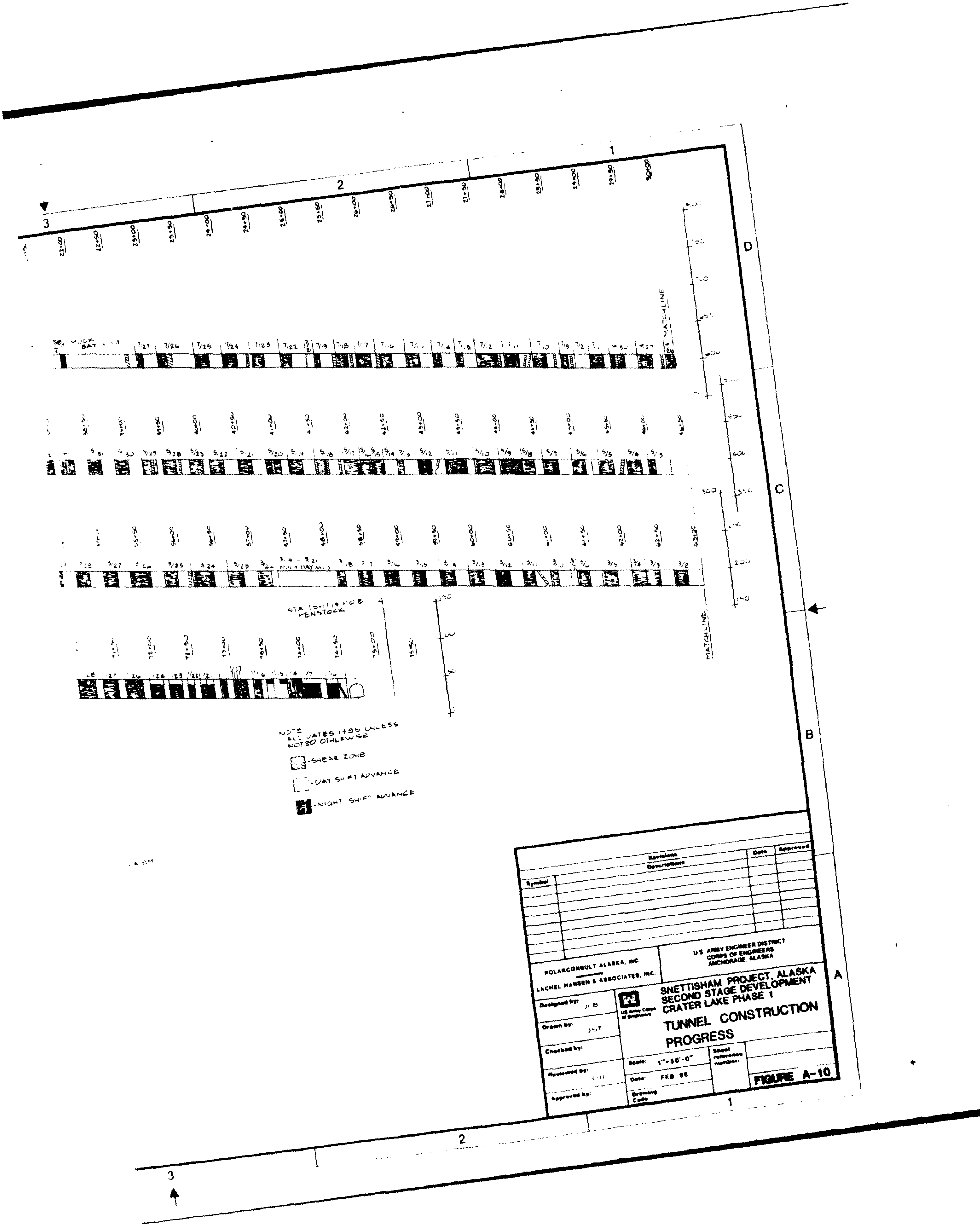
NOTE:
THIS FIGURE IS TAKEN DIRECTLY FROM DOCUMENTS SUPPLIED BY THE CONTRACTOR TO THE CORP. OF ENGINEERS.

BLAST PATTERN FOR POWERHOUSE MACHINE SHOP PLUG

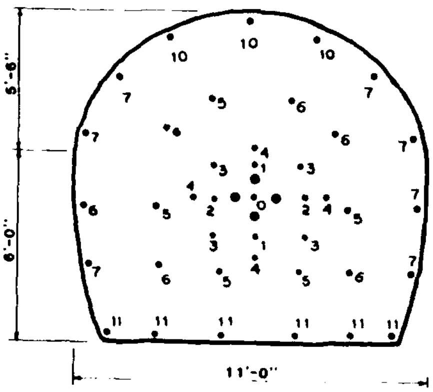
LACHEL & ASSOCIATES
GOLDEN, COLORADO

FIGURE A-9





MATCHLINE
STA 15+11.4 P.O.B. PENSTOCK
NOTE: ALL DATES 1985 UNLESS NOTED OTHERWISE
-SHEAR ZONE
-DAY SHIFT ADVANCE
-NIGHT SHIFT ADVANCE
Revisions
Descriptions
Date
Approved
Symbol
POLARCONSULT ALASKA, INC.
LACHEL HANSEN & ASSOCIATES, INC.
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1
TUNNEL CONSTRUCTION PROGRESS
Designed by: JCB
Drawn by: JST
Checked by:
Reviewed by:
Approved by:
Scale: 1"=50'-0"
Date: FEB 86
Drawing Code:
Sheet reference number:
FIGURE A-10



MODIFIED HORSESHOE SECTION

STA. 13+50 TO 56+00

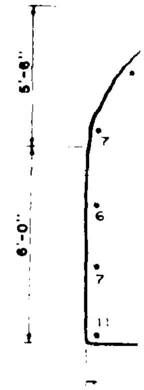
TUNNEL DELAYS	
0	1
1	2
2	2
3	4
4	4
5	5
6	6
7	7
8	0
9	0
10	3
11	6
12	0

DRILL DEPTH 10
DEPTH PULLED 10
POWDER FACTOR 7.3
HOLES LOADED 50
POWDER/HOLE ______
SQ. FT. 131 CY. 48.5

ANFO (PRILL) 245
T-2 (LBS.) 18
TOVEX 220 (LBS.) 90
PRIMER CORD (FT.) 130
FUSE (FT.) 32
NO. OF CAPS 57
BEGIN STATION 31+20
END STATION 31+10

ITEM # 4
DATE 6-25 TIME 1:30
SHOT # 2 628
ROUND # 413
SHIFTER C.P.

REMARKS: -30% HOLES VISIBLE. ALIGNMENT ON RIGHT FAIR. LOTS OVERBREAK FROM SPRINGLINE DOWN. ROCK VERY BLOCKY. ALIGNMENT ON LEFT GOOD, ROCK SEEMS BETTER.



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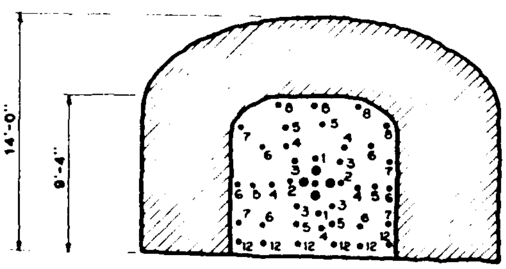


ENLARGED PENSTOCK

APPROXIMATELY STA 68+50 TO 75+17

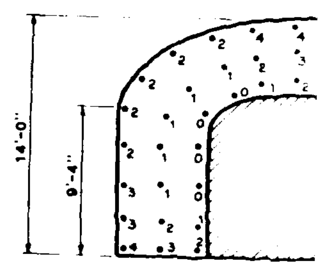
TUNNEL DELAYS	
0	1
1	2
2	2
3	4
4	5
5	6
6	4
7	4
8	5
9	0
10	0
11	0
12	6

DRILL DEPTH 10 *
DEPTH PULLED 9 *
POWDER FACTOR 10.00
HOLES LOADED 46 *
POWDER/HOLE ______

T-2 (LBS.) ______ *
TOVEX 220 (LBS.) 340 *
PRIMER CORD (FT.) 35 *
FUSE (FT.) 16 *
NO. OF CAPS 52 *
BEGIN STATION 73+12
END STATION 73+03

ITEM # 5
DATE 1-17 TIME 5:40
SHOT # 114
SHIFTER C.P.

REMARKS:



ENLARGED PE

APPROXIMATELY STA

TUNNEL DELAYS	
0	6
1	11
2	15
3	7
4	8
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0

DRILL DEPTH ______
DEPTH PULLED ______
POWDER FACTOR ______
HOLES LOADED ______
POWDER HOLE ______

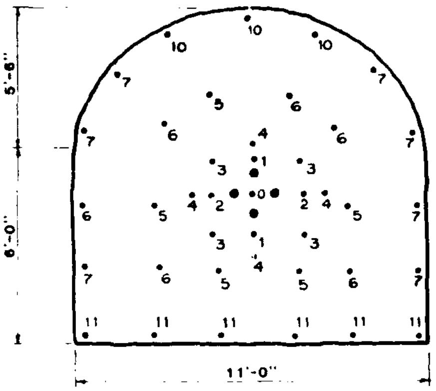
TOVEX 100 (LBS.) ______
T-2 (LBS.) ______
TOVEX 220 (LBS.) ______
PRIMER CORD (FT.) ______
FUSE (FT.) ______
NO. OF CAPS ______
BEGIN STATION ______
END STATION ______

REMARKS:
HOLE ALIGNMENT GOOD OVER 30% PERIMETER

3 | 2 | 1

4
TIME 1 30
628
413
C.P.

IR LOTS
VERY BLOCKY.
TTER



STRAIGHT LEG SECTION

STA. 56+00 TO 68+50

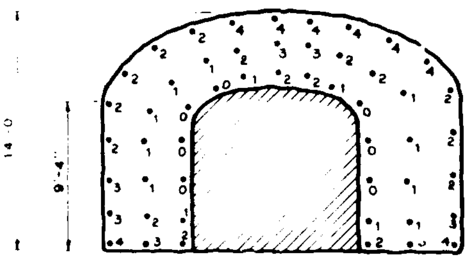
TUNNEL DELAYS	
0	1
1	2
2	2
3	4
4	4
5	5
6	6
7	7
8	0
9	0
10	3
11	6
12	0

DRILL DEPTH 10 *
DEPTH PULLED 9 *
POWDER FACTOR 6.4
HOLES LOADED 43 *
POWDER HOLE
SQ. FT. 135 CY. 45

ITEM # 4
DATE 3-13 TIME 12:20 *
SHOT # 309
ROUND # 1 96
SHIFTER C.P. *

ANFO (PRILL) *
T-2 (LBS.) 16 *
TOVEX 220 (LBS.) 360 *
PRIMER CORD (FT.) 170 *
FUSE (FT.) 17 *
NO. OF CAPS 49 *
BEGIN STATION 60+04
END STATION 59+95

REMARKS: -30% HOLES VISIBLE. ALIGNMENT OK. BUT FAIR AMOUNT OF OVERBREAK DUE TO SLABS AND BLOCKY ROCK. BOTH SIDES



1' 0' 1' 2' 3' 4' 5' 6' 7'

GRAPHIC SCALE IN FEET

ENLARGED PENSTOCK

APPROXIMATELY STA. 68+50 TO 75+17

DELAYS	
	6
	11
	15
	7
	8
	0
	0
	0
	0
	0
	0
	0
	0

DRILL DEPTH 10
DEPTH PULLED 9
POWDER FACTOR 7.63
HOLES LOADED 51
POWDER HOLE

ITEM # 5
DATE 1-17 TIME 5-40
SHOT # 2 113
SHIFTER C.P.

TOVEX 100 (LBS.) 75
T-2 (LBS.) 35
TOVEX 220 (LBS.) 200
PRIMER CORD (FT.) 300
FUSE (FT.) 16
NO. OF CAPS 57
BEGIN STATION 73+39
END STATION 73+30

S
IGNMENT GOOD OVER 30% PERIMETER HOLES SHOWING NO SIGNIFICANT OVERBREAK.

Revisions			
Symbol	Descriptions	Date	Approved

POLARCONSULT ALASKA, INC
LACHEL HANSEN & ASSOCIATES, INC

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

US Army Corps of Engineers

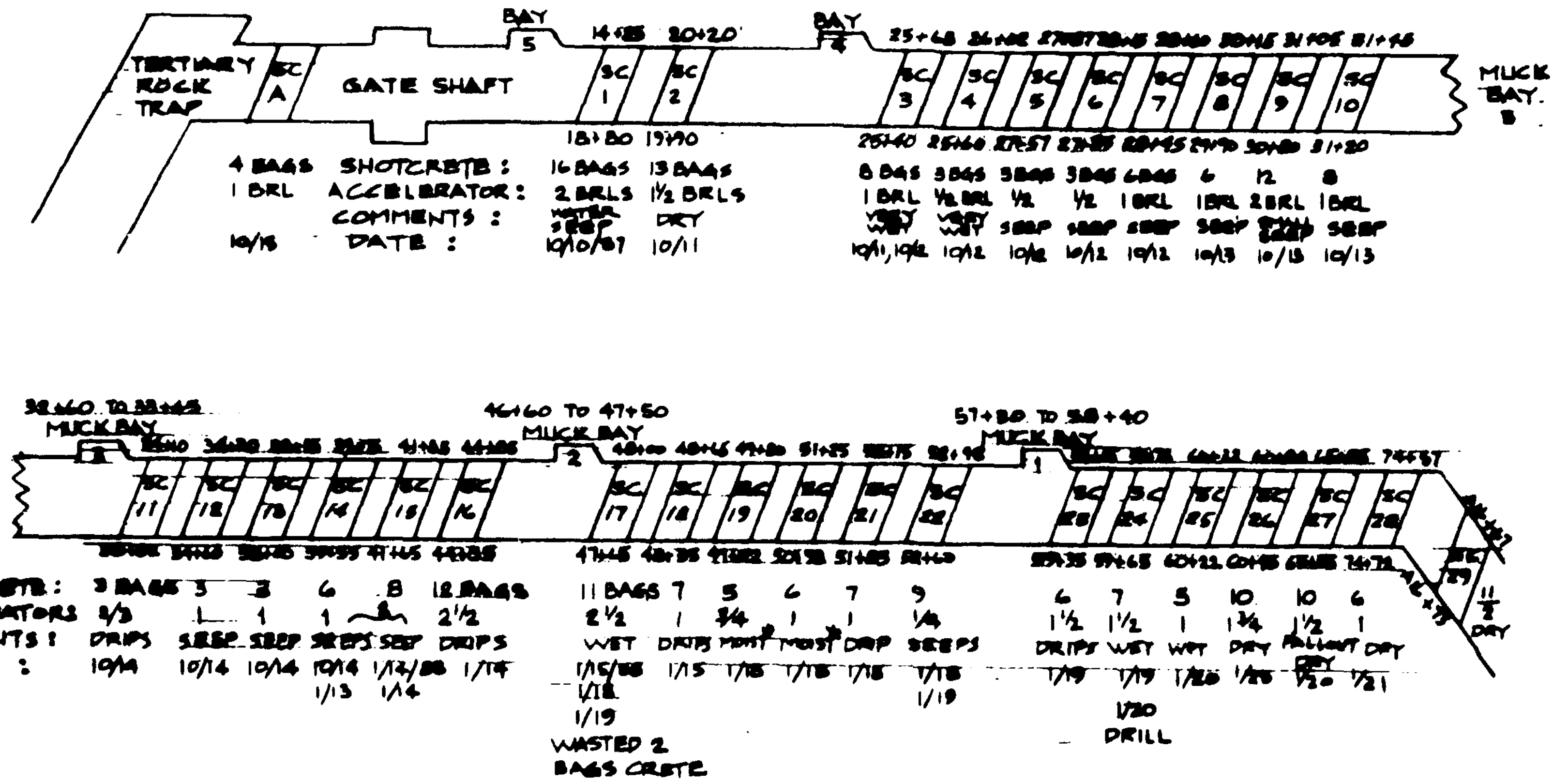
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1

BLASTING PLAN
TYPICAL

Designed by:	DL
Drawn by:	IT
Checked by:	EA
Reviewed by:	
Approved by:	
Scale:	AS SHOWN
Date:	February 1986
Drawing Code:	
Sheet reference number:	

FIGURE A-11

3 | 2 | 1



SHOTCRETE PLACEMENT BY STATION

SHOTCRETE	BAGS
10/10/87	16
10/11/87	13
10/12/87	18
10/13/87	20
10/14/87	18
10/15/87	4
1/13/88	10 + 2 BAGS WASTED
1/14/88	14
1/15/88	16
1/18/88	22
1/19/88	20
1/20/88	22
1/21/88	20

\# INDICATES AREAS WHERE SMALL FALLOUTS WERE PATCHED BUT NOT RECORDED.

P INDICATES LESS THAN 1/2 BAG

ACCELERATOR USAGE PER SECTION IS APPROXIMATE.

SHOTCRETE PER DAY IS EXACT.

SHOTCRETE PLACEMENT CHART
CRATER LAKE MAIN CONTRACT
DACW 85-86-C-0019

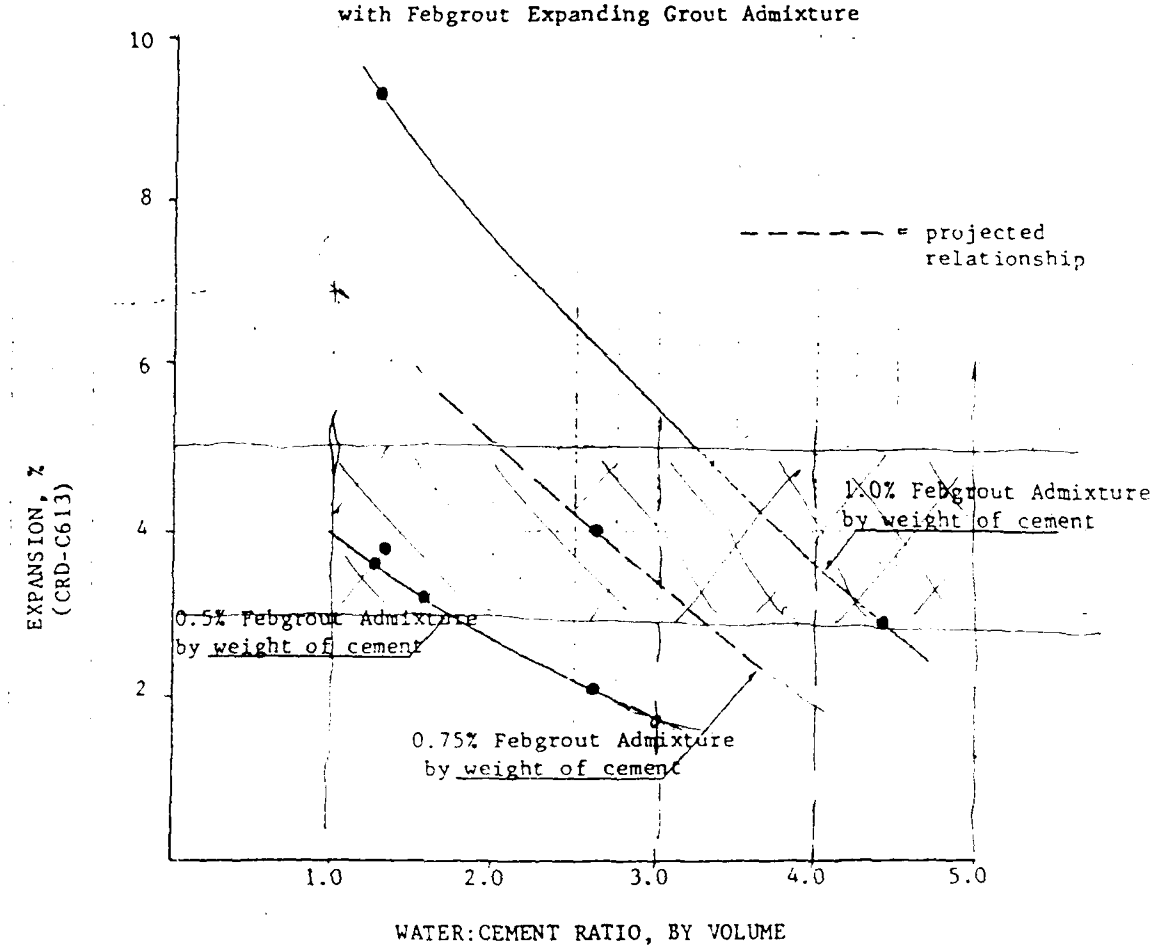
FIGURE A-12

LACHEL & ASSOCIATES
GOLDEN, COLORADO

NPDEN-G-L (87-C-306)

CRATER LAKE MAIN CONTRACT
Second Stage Development
Snettisham, Alaska

Expansion versus Water:Cement Ratio
for Neat Cement Grout Mixes Batched
with Febgrout Expanding Grout Admixture



NOTE: Project Expansion Limits are 3.0 to 5.0 Percent

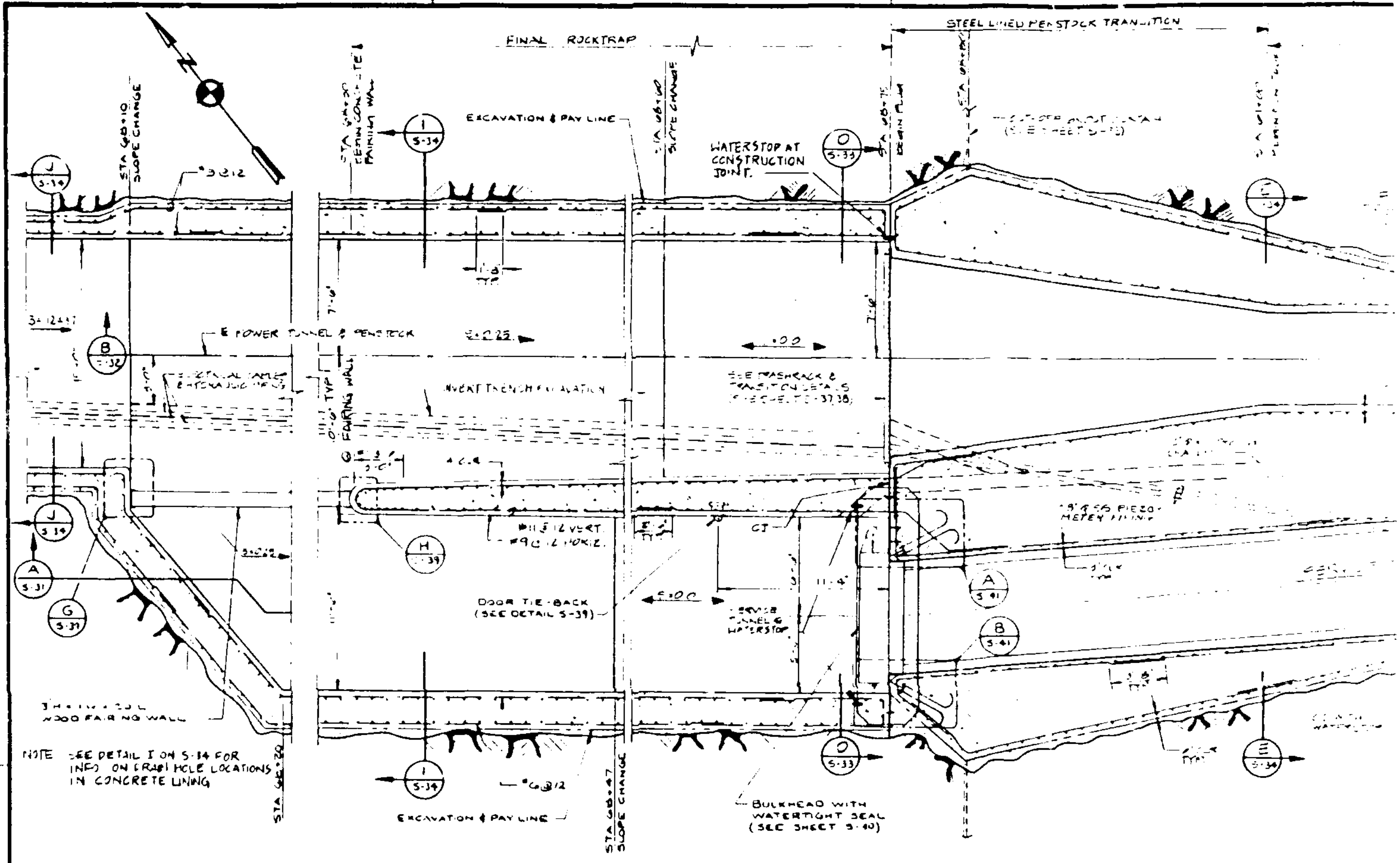
NOTE:
THIS FIGURE IS TAKEN DIRECTLY FROM DOCUMENTS SUPPLIED BY THE CONTRACTOR TO THE CORP. OF ENGINEERS.

NPDL
Oct 86

GROUT MIX DESIGN

LACHEL & ASSOCIATES

FIGURE A-13

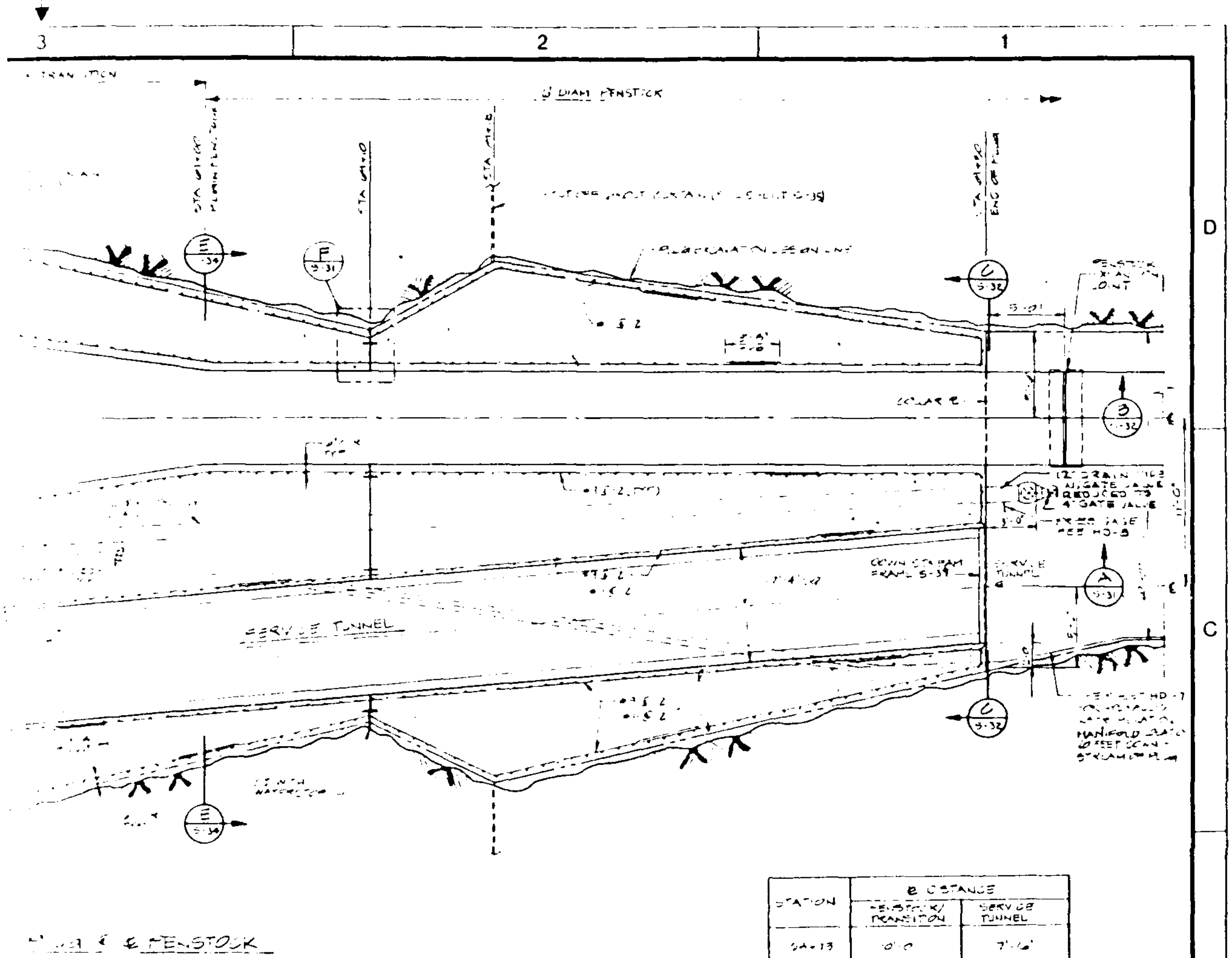


SECTIONAL PLAN OF TUNNEL PLUG & ℄ PENSTOCK

SCALE: 1/4"=1'-0"

GENERAL NOTES:

1. REFER TO SHEETS S-1 & S-3 FOR LOCATION OF PLUG IN POWER TUNNEL. CONSULT CONCRETE SPEC
2. TUNNEL PLUG CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH OF 3,000 PSI.
3. CONCRETE REINFORCEMENT SHALL HAVE A MINIMUM YIELD STRENGTH OF 60,000 PSI IN CONFORMANCE WITH ASTM A615.
4. CONSTRUCTION JOINTS SHALL BE LOCATED TO MINIMIZE CRACKING CAUSED BY INITIAL SHRINKAGE AND TO FACILITATE POURING OPERATIONS WITH MAXIMUM LIFT HEIGHTS OF 5 FT FOR MASS CONCRETE POURS, 10 FT FOR WALLS GREATER THAN 18 IN. THICK, AND 5 FT FOR WALLS UNDER 18 IN. THICK, UNLESS OTHERWISE NOTED OR APPROVED.
5. MINIMUM COVER FOR REINFORCEMENT AT PLUG SHALL BE 6" FOR CONCRETE POURED AGAINST ROCK AND AROUND STEEL LINER, 4" FOR CONCRETE EXPOSED TO FLOWING WATER, AND 3" FOR CONCRETE NOT EXPOSED TO FLOWING WATER.
6. SPLICES IN CONCRETE REINFORCEMENT SHALL BE STAGGERED BETWEEN ADJACENT BARS SO THAT NO MORE THAN 50 PERCENT OF THE BARS ARE SPLICED WITHIN A LENGTH OF 34 BAR DIAMETER FOR #7, 40 BAR DIAMETER FOR #9 & #11 AROUND PLUG LINER & SERVICE TUNNEL, & 55 BAR DIAMETER FOR #11 AROUND PLUG PERIMETER.
7. MINIMUM LAP SPLICE LENGTHS IN LONGITUDINAL REINFORCEMENT SHALL BE 2'-6" FOR #7 BARS AND 3'-8" FOR #9 BARS, UNLESS NOTED OTHERWISE.
8. HOOP REINFORCEMENT AROUND STEEL LINER SHALL HAVE A MINIMUM SPLICE LENGTH OF 4'-8". HOOP REINFORCEMENT AT PERIMETER OF PLUG EXCAVATION SHALL HAVE A MINIMUM SPLICE LENGTH OF 5'-8".
9. ADDITIONAL REINFORCEMENT DETAILS SHALL CONFORM TO ACI 318-93 MANUAL.



... IN POWER

... COMPRESSIVE

... YIELD STRENGTH
... BARS

... TO MINIMIZE CRACKING
... FACILITATE POURING
... OF 5 FT FOR MASS
... GREATER THAN 18 IN. THICK,
... THICK, UNLESS OTHERWISE

... AT PLUG SHALL BE 6" FOR
... AROUND STEEL LINER, 4" FOR
... AND 3" FOR CONCRETE NOT

... SHALL BE STAGGERED
... MORE THAN 50 PERCENT OF
... LENGTH OF 30 BAR DIAMETER FOR
... AROUND PLUG LINER &
... FOR ALL AROUND PLUG

... LONGITUDINAL REINFORCEMENT
... 8" FOR #9 BARS, UNLESS

... LINER SHALL HAVE A MINIMUM
... REINFORCEMENT AT PERIMETER
... MINIMUM SPLICE LENGTH OF

... SHALL CONFORM TO ACI 318-83

10. PLUG LINER STEEL SHALL CONFORM TO ASTM A517 GRADE F AND SHALL BE FABRICATED AND TESTED IN ACCORDANCE WITH SECTION VIII OF ASTM BOILER & PRESSURE VESSEL CODES

11. WELDING SHALL BE IN ACCORDANCE WITH STRUCTURAL STEEL WELDING CODE AWS D1.1. ELECTRODES SHALL BE AS INDICATED IN SPECS.

12. ROCK EXCAVATION SHALL BE COMPLETED, CLEANED, AND FREE OF WATER BEFORE CONCRETE PLACEMENT AT PLUG, SUBJECT TO APPROVAL OF CONTRACTING OFFICER.

13. ELECTRICAL CABLES AND TUBING ATTACHED TO RESTEEL WITHIN INVERT TRENCH SHALL BE PROTECTED BY USE OF ELECTRICAL INSULATION TAPE AT ATTACHMENT POINTS.

14. ELECTRICAL BOX IN INVERT TRENCH SHALL BE LOCATED AS SHOWN ON SHEET S-30.1.

15. DRAIN PIPE THROUGH TUNNEL PLUG SHALL BE 12" DIAMETER X-STRONG IN CONFORMANCE WITH ASTM A53, GRADE B, TYPE S.

STATION	℄ DISTANCE	
	PENSTOCK/ TRANSITION	SERVICE TUNNEL
24+13	0'-0	7'-6'
28+64	2'-0'	0-0'
29+0	5'-'	3-'
29+6	0'-0'	0'-0'
29+50	3'-'	3-'

℄ DISTANCE REFERS TO HORIZONTAL DISTANCE MEASURED FROM ℄ OF SERVICE TUNNEL OR PENSTOCK TO THE EXCAVATED ROCK FACE DESIGN LINE. SEE SECTIONS SHEET S-28 & 29

SCALES IN FEET

CONTRACT NO DACW85-86-C-0019

Revisions			
Symbol	Descriptions	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE MAIN CONTRACT

Designed by: RG
Drawn by: TB

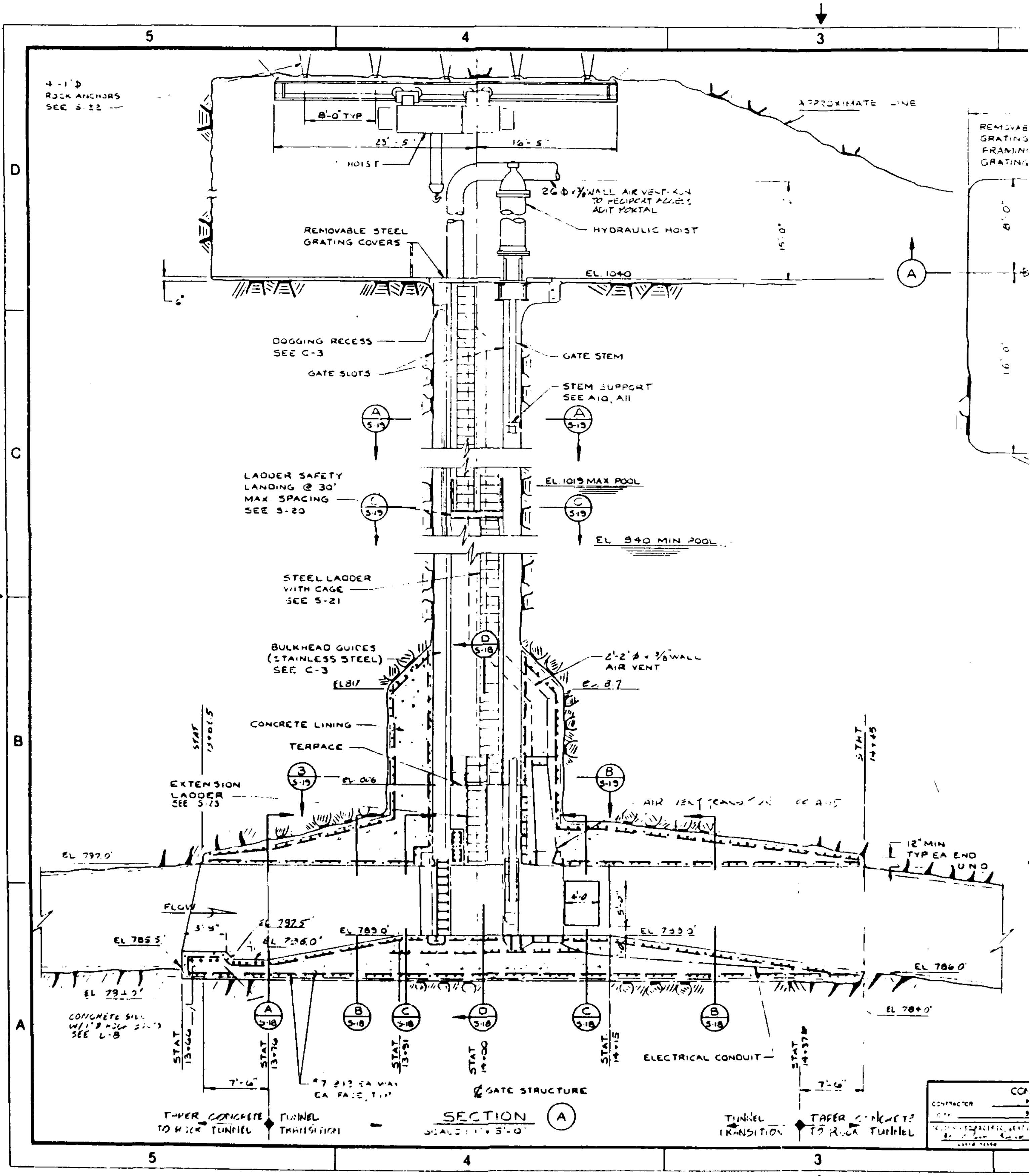
POWER TUNNEL PLUG PLAN

Scale: AS SHOWN
Sheet reference number: AS-8LT
Drawing: 1-SNE-98-08
Code: 19-05/30
S-30
Sheet 170 of 252

INV. NO. DACW 85-86-B-0002

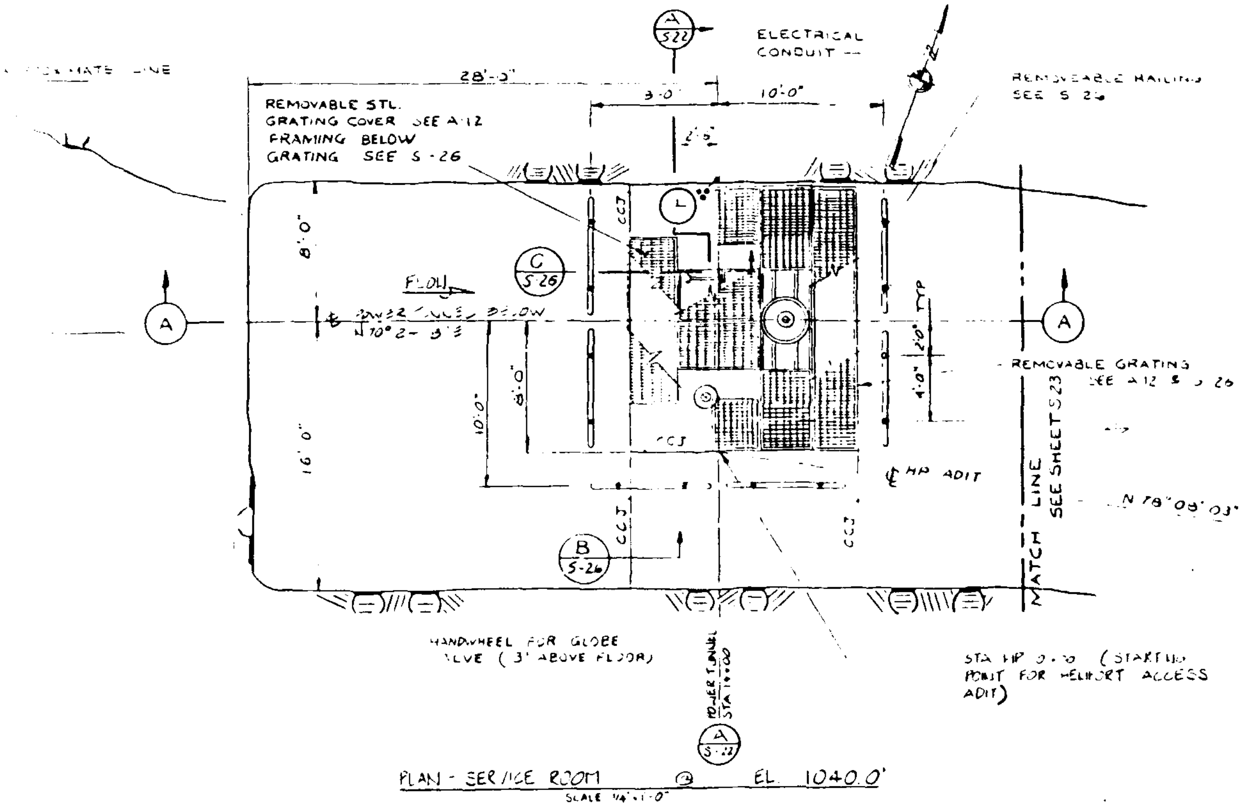
FIGURE A-14

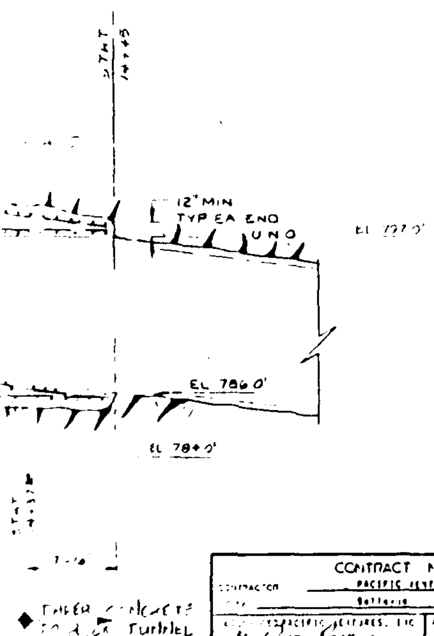
LACHEL & ASSOCIATES
GOLDEN, COLORADO



SECTION (A)

SCALE: 1" = 5'-0"





NOTES:

1. ROCK BOLTS SHALL BE 1" Ø (HOLLOW CORE ROCK BOLTS, RESIN ANCHOR ROCK BOLTS OR APPROVED EQUAL). TWO BOLTS SHALL BE TESTED TO 35,000 LBS., AS SELECTED BY CONTRACTING OFFICER. DEPTH OF BOLTS SHALL BE 10 FT. MINIMUM FOR HOIST ANCHORS & 8 FT MINIMUM FOR ALL OTHERS. CONTRACTOR SHALL SUBMIT PLAN FOR TYPE OF BOLTS FOR APPROVAL BY CONTRACTING OFFICER.

2. ANCHOR BOLTS IN CONCRETE FOR MECHANICAL EQUIPMENT SHALL BE GROUTED-IN OR CAST-IN PLACE. CONTRACTOR SHALL SUBMIT PLAN FOR TYPE, SIZE, LENGTH & METHOD OF INSTALLATION FOR APPROVAL BY CONTRACTING OFFICER.

CONTRACT NO DACW85-86-C-0019
PACIFIC VENTURES, INC.

Revisions				
Symbol	Action	Descriptions	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE

PLAN @ EL. 1040.0' & SECTION

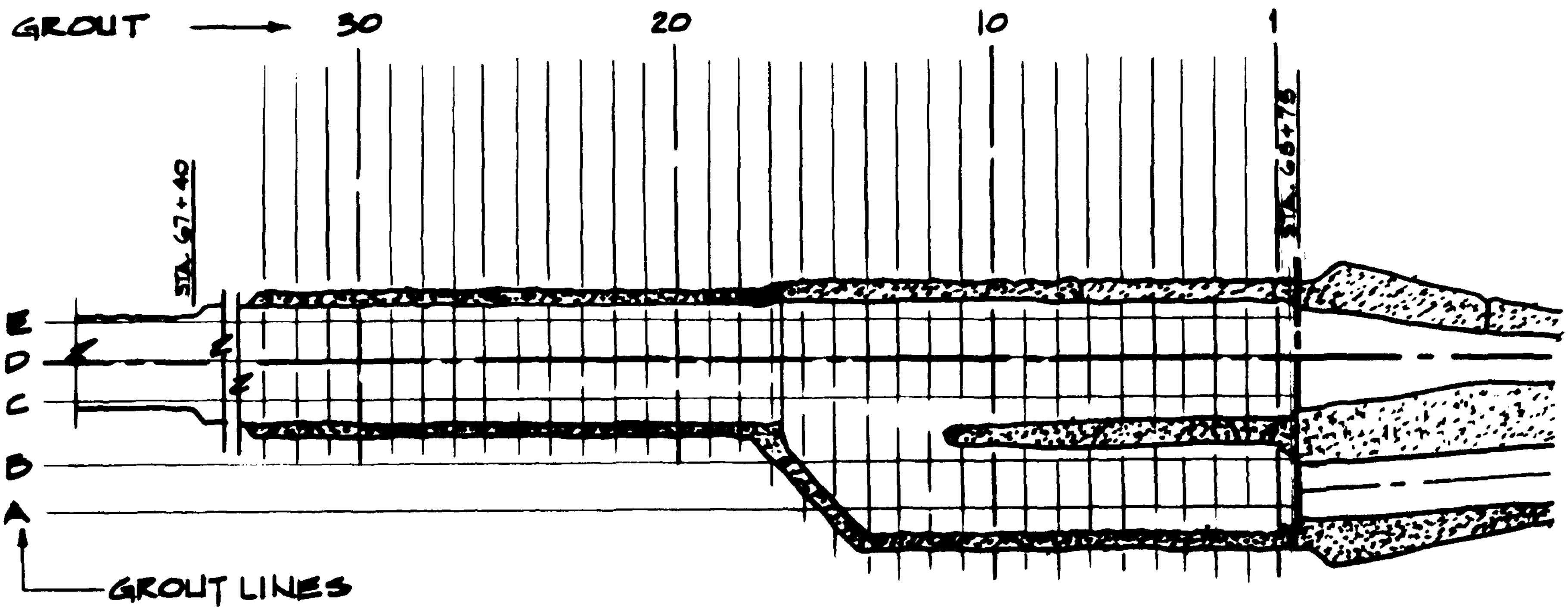
Designed by: JN
Drawn by: GEK
Checked by: CHIEF, STRUCTURES SEC.
Reviewed by: CHIEF, DESIGN BRANCH
Approved by: CHIEF, ENGINEERING DIV.

Scale: AS SHOWN
Sheet reference number: AS-BLT
Drawing: 3-SNE-96-08-
Code: 10-05/10
S-16
Sheet 158 of 252

INV. NO. DACW 85-86-B-0002

FIGURE A-15

LACHEL & ASSOCIATES
GOLDEN, COLORADO



NEW TRANSITION, ROCKTRAP & PLUG PLAN
@ ℄ PENSTOCK

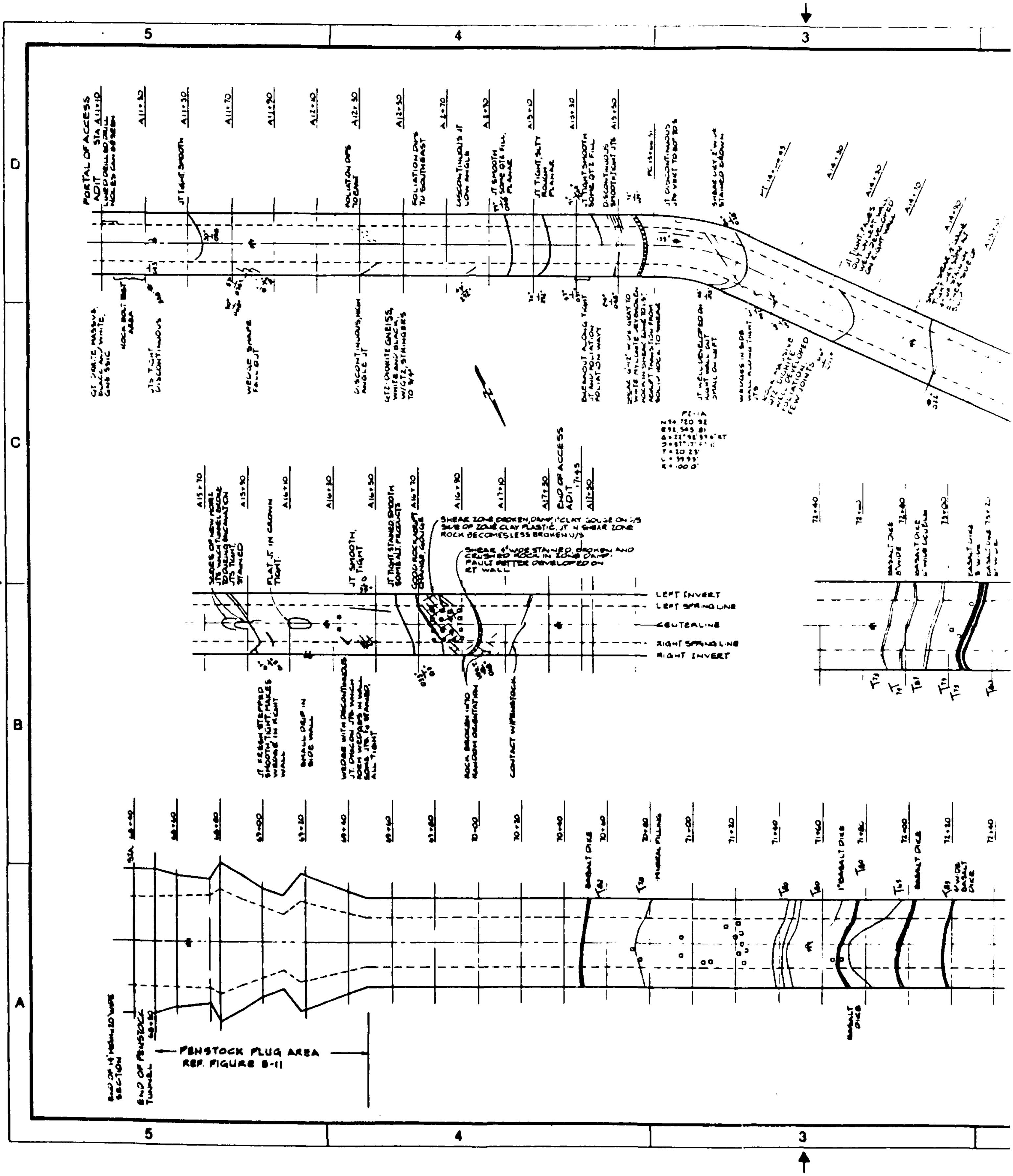
LOCATION OF GROUT HOLES FOR CONTACT GROUTING OF TUNNEL LINER UPSTREAM OF TUNNEL PLUG.

PLAN-
GROUT HOLE LOCATION
-TATIONING

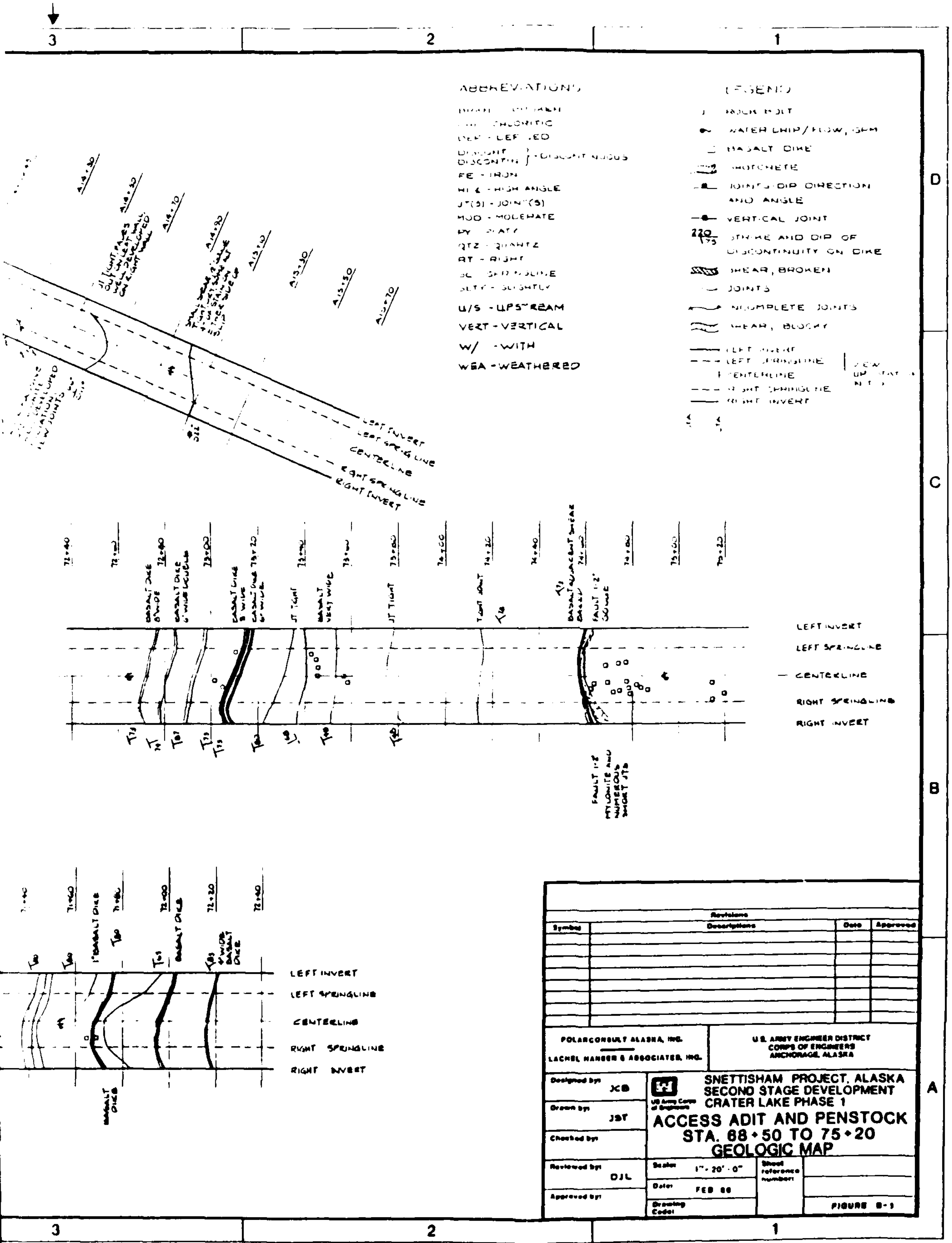
APPENDIX B

GEOLOGIC MAPS OF TUNNELS, SHAFTS AND ADITS

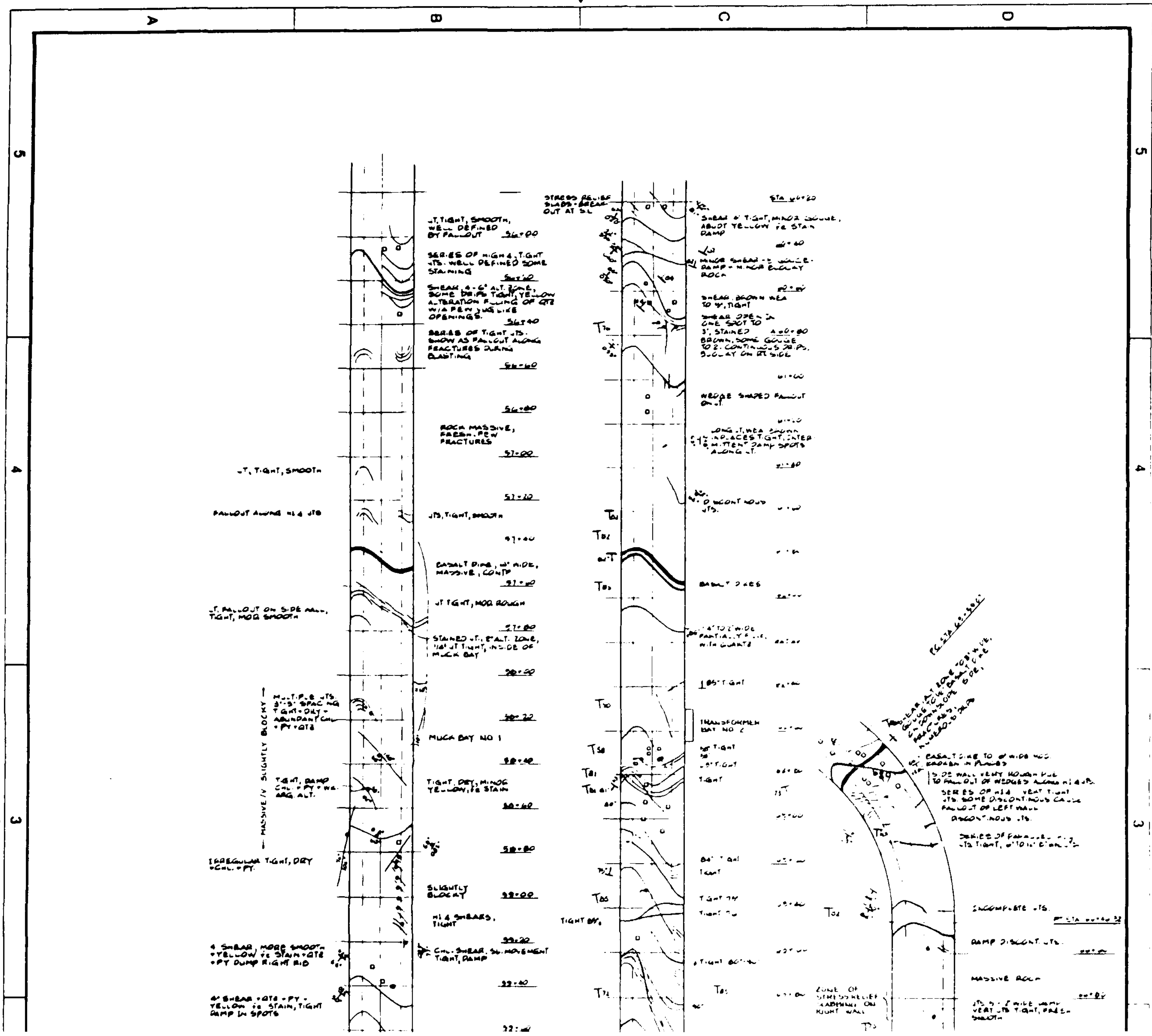
APPENDIX B - Geologic Mapping



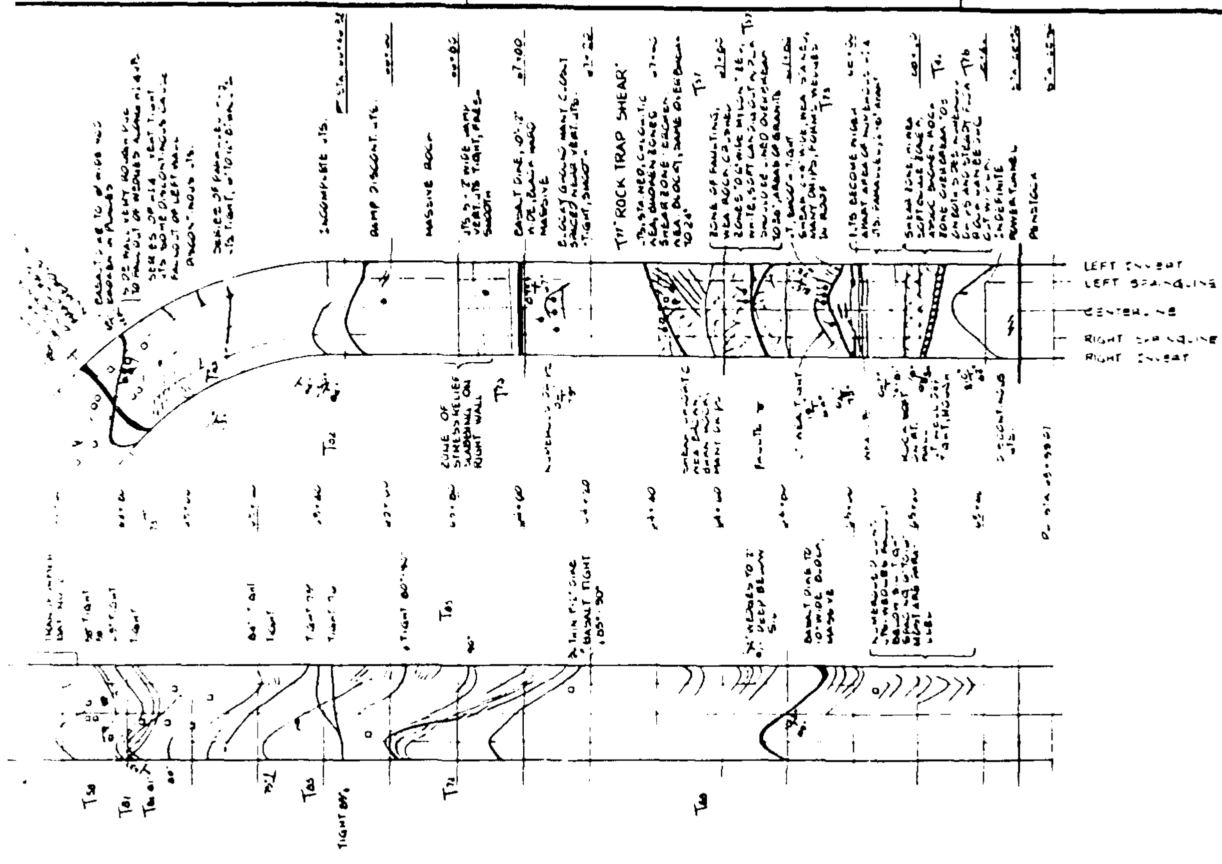
PORTAL OF ACCESS ADIT STA A11+10
END OF ACCESS ADIT
LEFT INVERT
LEFT SPRING LINE
CENTERLINE
RIGHT SPRING LINE
RIGHT INVERT
BASALT DIKE
PENSTOCK PLUG AREA
REF. FIGURE B-11
END OF PENSTOCK TUNNEL

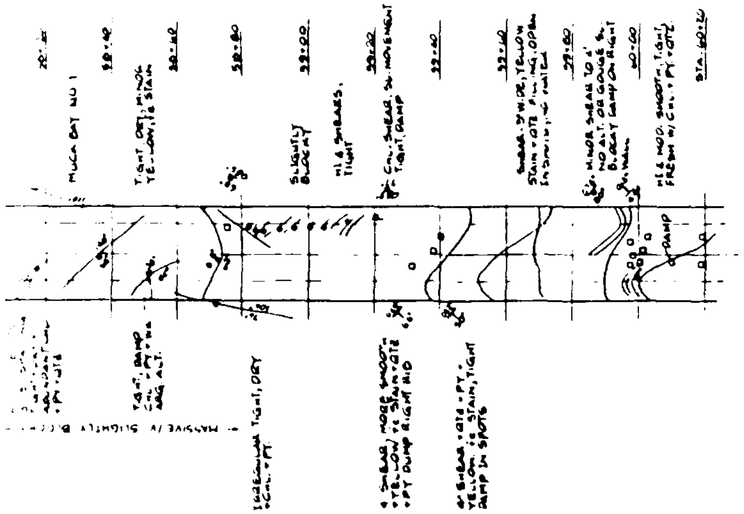

ABBREVIATIONS
FE - IRON
HI ∠ - HIGH ANGLE
JT(S) - JOINT(S)
MOD - MODERATE
QTZ - QUARTZ
RT - RIGHT
U/S - UPSTREAM
VERT - VERTICAL
W/ - WITH
WEA - WEATHERED
LEGEND
WATER DRIP/FLOW, GPM
BASALT DIKE
JOINTS - DIP DIRECTION AND ANGLE
VERTICAL JOINT
STRIKE AND DIP OF DISCONTINUITY ON DIKE
SHEAR, BROKEN
JOINTS
INCOMPLETE JOINTS
SHEAR, BLOCKY
RIGHT INVERT
LEFT INVERT
LEFT SPRINGLINE
CENTERLINE
RIGHT SPRINGLINE
RIGHT INVERT
JT TIGHT
FAULT 1-2" GOUGE
FAULT 1-2" MYLONITE AND NUMEROUS TIGHT JTS
1' BASALT DIKE
BASALT DIKE
Revisions
Symbol
Descriptions
Date
Approved
POLARCONSULT ALASKA, INC.
LACHEL HANSEN & ASSOCIATES, INC.
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
Designed by: XB
Drawn by: JST
Checked by:
Reviewed by: DJL
Approved by:
US Army Corps of Engineers
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1
ACCESS ADIT AND PENSTOCK
STA. 68+50 TO 75+20
GEOLOGIC MAP
Scale: 1" = 20' - 0"
Date: FEB 88
Drawing Code:
Sheet reference number:
FIGURE B-1

1



STA 60+20
STRESS RELIEF SLABS BREAK OUT AT SL
JT, TIGHT, SMOOTH, WELL DEFINED BY FALLOUT
56+00
SERIES OF HIGH ∠ TIGHT JTS. WELL DEFINED SOME STAINING
SHEAR, 4-6" ALT. ZONE, SOME DRIPS TIGHT, YELLOW ALTERATION FILLING OF QTZ W/A FEW VUG LIKE OPENINGS.
56+40
SERIES OF TIGHT JTS. SHOW AS FALLOUT ALONG FRACTURES DURING BLASTING
56+60
56+80
ROCK MASSIVE, FRESH, FEW FRACTURES
57+00
JT, TIGHT, SMOOTH
57+20
FALLOUT ALONG HI ∠ JTS
JTS, TIGHT, SMOOTH
BASALT DIKE, 1/4" WIDE, MASSIVE, CONT
JT TIGHT, MOD ROUGH
JT. FALLOUT ON SIDE WALL, TIGHT, MOD SMOOTH
STAINED JT. & ALT. ZONE, 1/8" JT TIGHT, INSIDE OF MUCK BAY
MULTIPLE JTS 3"-5" SPACING TIGHT-DRY-ABUNDANT CHL + PY + QTZ
MUCK BAY NO 1
MASSIVE W/ SLIGHTLY BLOCKY
TIGHT, DAMP CHL + PY + WK ARG. ALT.
TIGHT, DRY, MINOR YELLOW FE STAIN
58+80
IRREGULAR TIGHT, DRY + CHL + PY
SLIGHTLY BLOCKY
59+00
HI ∠ SHEARS, TIGHT
59+20
4 SHEAR, MORE SMOOTH + YELLOW FE STAIN + QTZ + PY DUMP RIGHT RIB
CHL. SHEAR, SL. MOVEMENT TIGHT, DAMP
59+40
4" SHEAR + QTZ + PY + YELLOW FE STAIN, TIGHT DAMP IN SPOTS
SHEAR 6" TIGHT, MINOR GOUGE, ABUNDANT YELLOW FE STAIN DAMP
SHEAR BROWN WEA TO 1/4", TIGHT
WEDGE SHAPED FALLOUT
BASALT DIKES
TRANSFORMER BAY NO 2
TIGHT
TIGHT DRY
ZONE OF STRESS RELIEF SLABBING ON RIGHT WALL
BASALT DIKE TO 6" WIDE MOD. BROKEN IN PLACES
INCOMPLETE JTS.
DAMP DISCONT. JTS.
MASSIVE ROCK





NOTE:
SEE FIG B-1 FOR LEGEND AND ABBREVIATIONS

Revisions			
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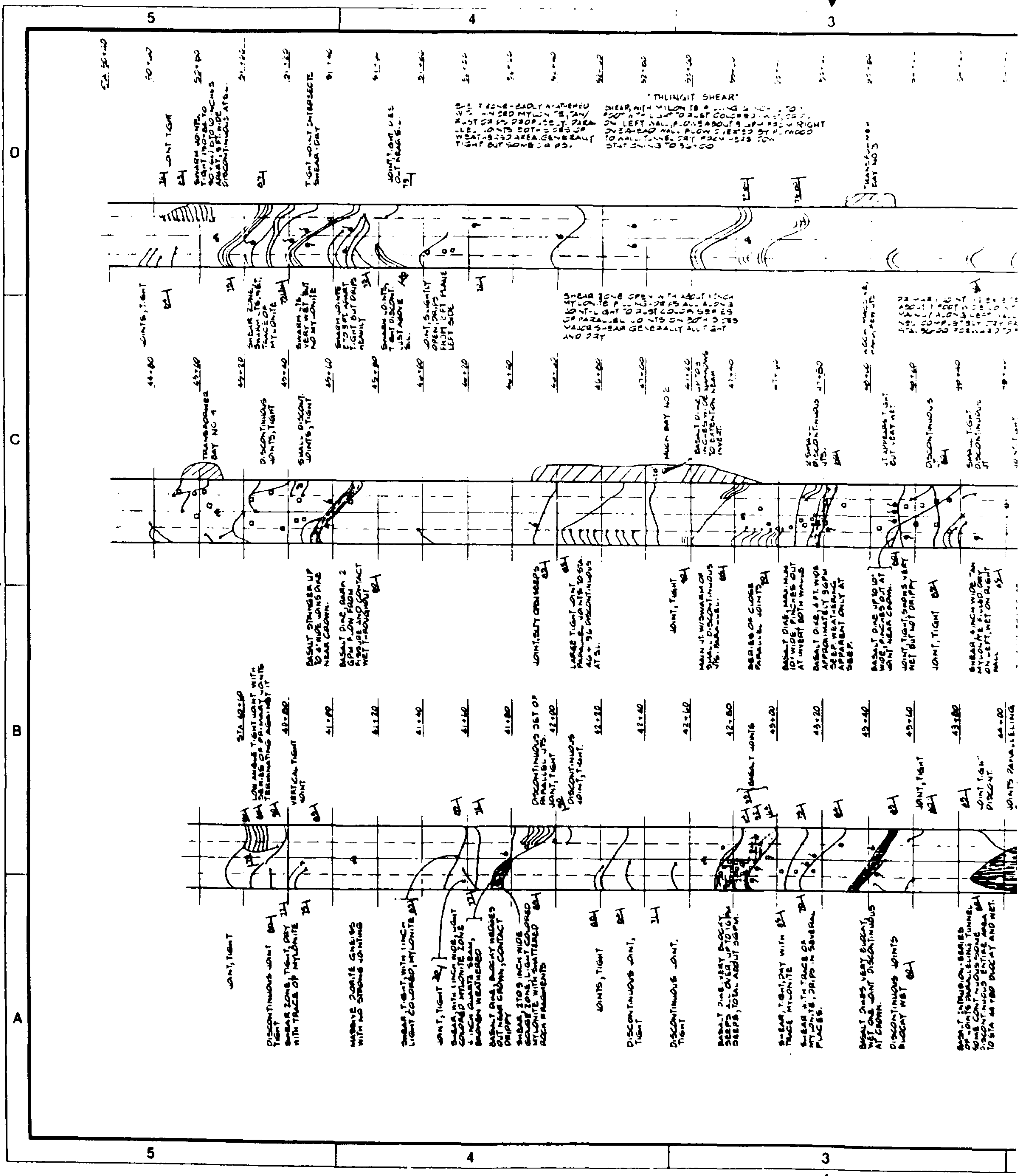
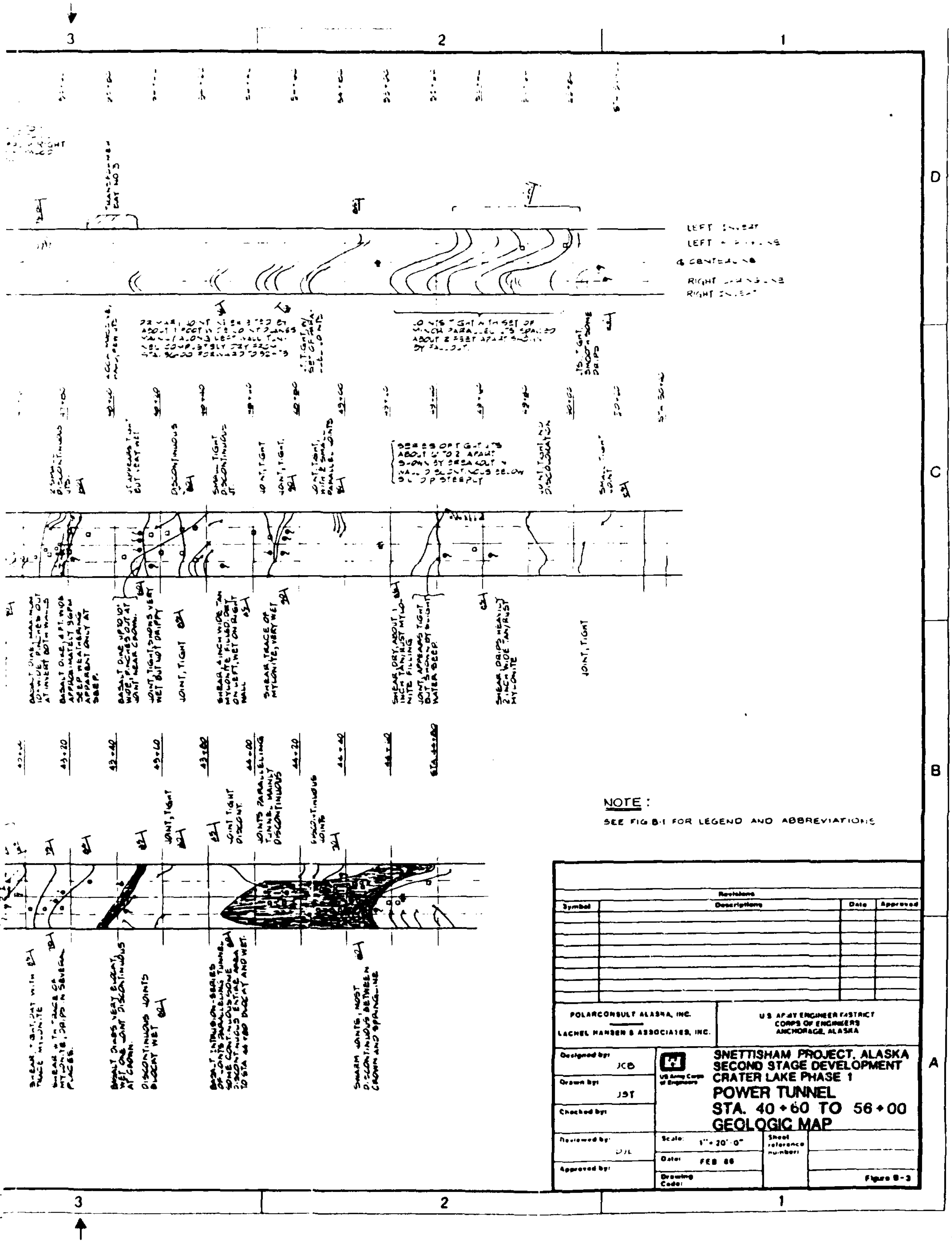
US Army Corps of Engineers

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1
POWER TUNNEL
STA. 56+00 TO 68+50
GEOLOGIC MAP

Designed by:	KB
Drawn by:	JBT
Checked by:	
Reviewed by:	DVL
Approved by:	
Scale:	1" = 20' 0"
Date:	FEB. 88
Drawing Code:	
Sheet reference number:	Figure B-2



"THLINGIT SHEAR"
TRANSFORMER BAY NO 4
TRANSFORMER BAY NO 3
JOINT, TIGHT
JOINTS, TIGHT
DISCONTINUOUS JOINTS
MASSIVE DIORITE GNEISS WITH NO STRONG JOINTING
5
4
3
D
C
B
A



NOTE :

SEE FIG. B-1 FOR LEGEND AND ABBREVIATIONS

Symbol	Revisions Descriptions	Date	Approved

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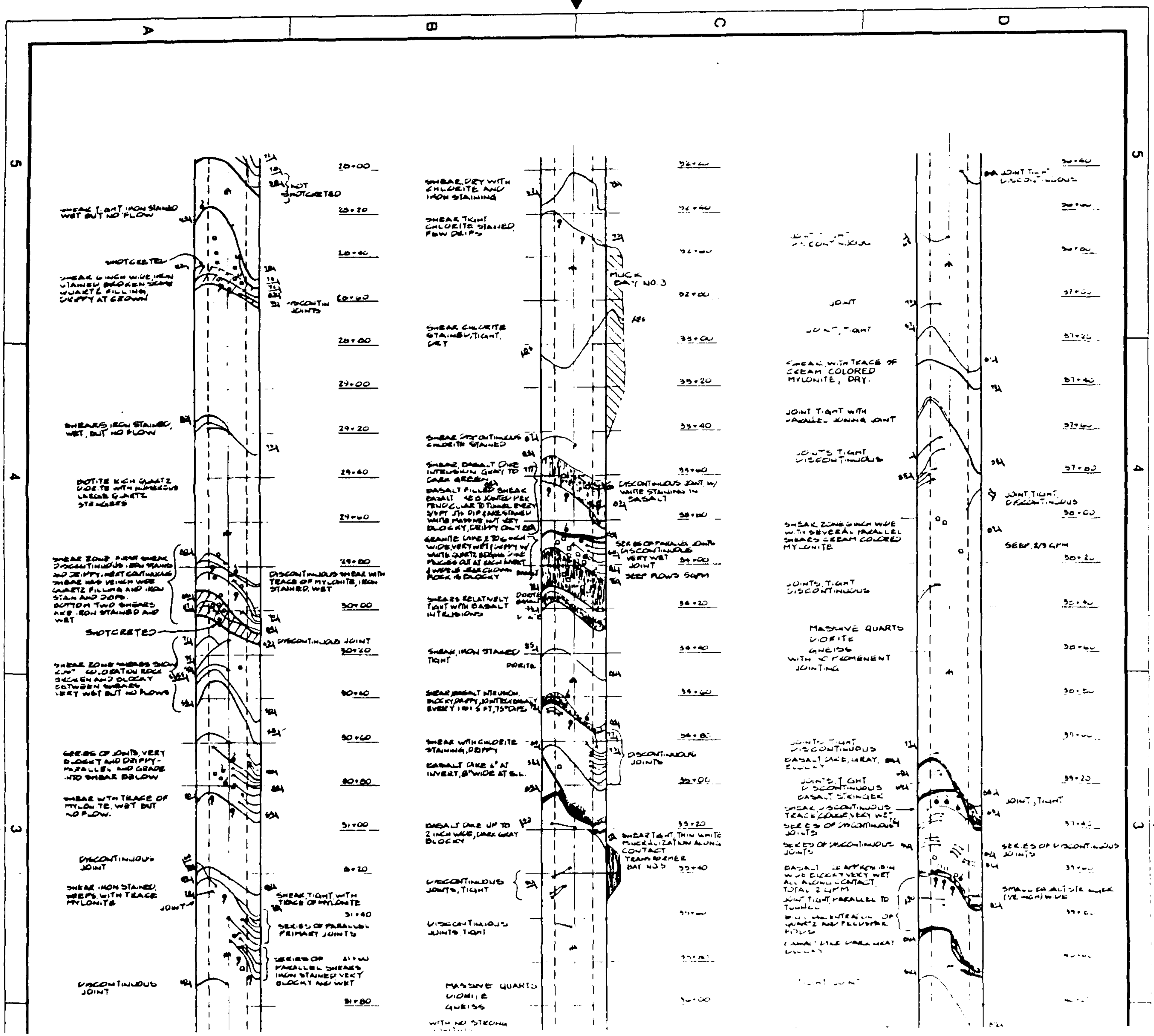
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

US Army Corps of Engineers

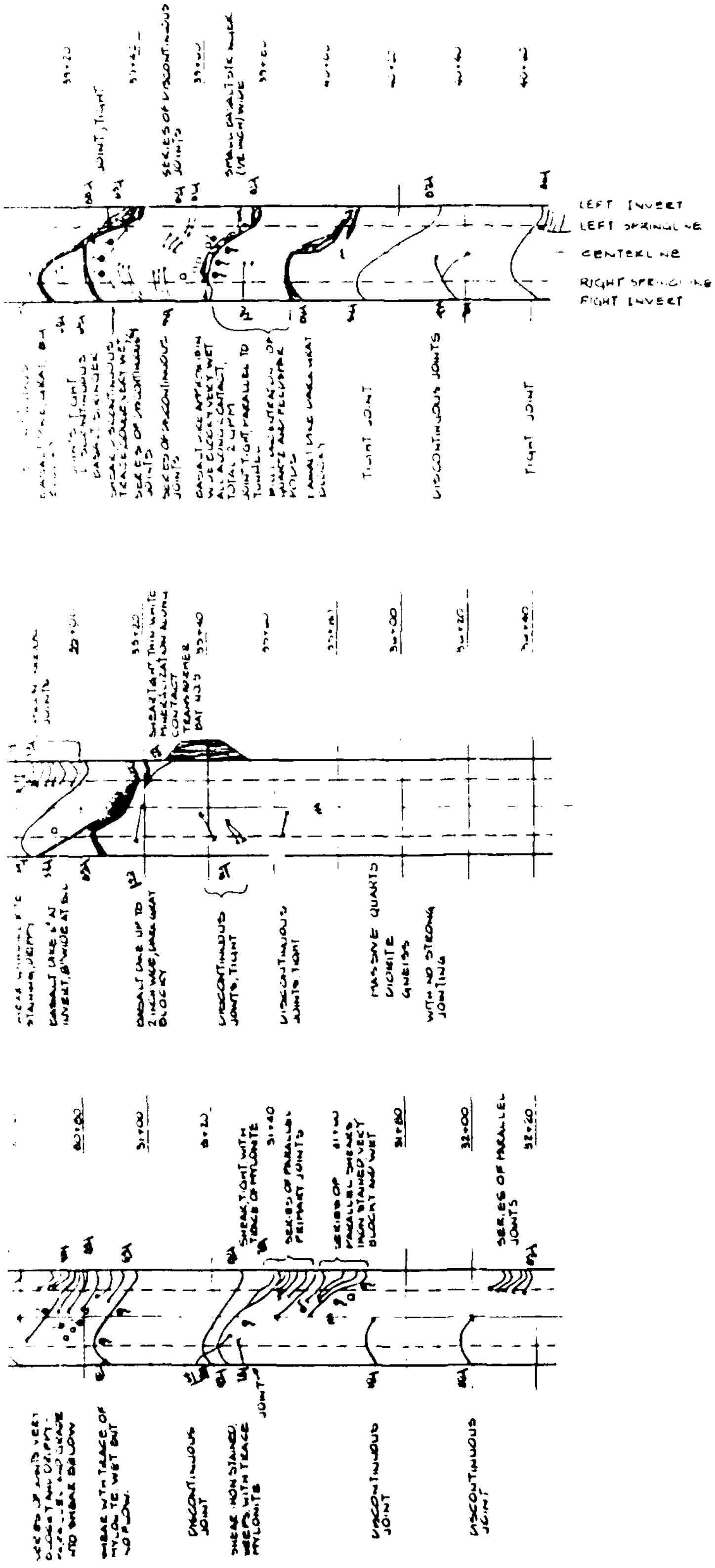
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1

POWER TUNNEL
STA. 40+60 TO 56+00
GEOLOGIC MAP

Designed by:	JCB
Drawn by:	JST
Checked by:	
Reviewed by:	DJL
Approved by:	
Scale:	1" = 20'-0"
Date:	FEB 88
Drawing Code:	
Sheet reference number:	
	Figure B-3



A
B
C
D
5
4
3
SHEAR, TIGHT, IRON STAINED WET BUT NO FLOW
NOT SHOTCRETED
SHOTCRETED
SHEAR 6 INCH WIDE, IRON STAINED, BROKEN SOME QUARTZ FILLING, DRIPPY AT CROWN
DISCONTIN JOINTS
SHEARS, IRON STAINED, WET, BUT NO FLOW
BIOTITE RICH QUARTZ DIORITE WITH NUMEROUS LARGE QUARTZ STRINGERS
DISCONTINUOUS SHEAR WITH TRACE OF MYLONITE, IRON STAINED, WET
SHOTCRETED
DISCONTINUOUS JOINT
SERIES OF JOINTS, VERY BLOCKY AND DRIPPY PARALLEL AND GRADE INTO SHEAR BELOW
SHEAR WITH TRACE OF MYLONITE, WET BUT NO FLOW.
DISCONTINUOUS JOINT
SHEAR, IRON STAINED, SEEPS, WITH TRACE MYLONITE
JOINT
SHEAR, TIGHT, WITH TRACE OF MYLONITE
SERIES OF PARALLEL PRIMARY JOINTS
SERIES OF PARALLEL SHEARS IRON STAINED VERY BLOCKY AND WET
DISCONTINUOUS JOINT
29+00
29+20
29+40
29+60
29+80
30+00
30+20
30+40
30+60
30+80
31+00
31+20
31+40
31+80
SHEAR, DRY WITH CHLORITE AND IRON STAINING
SHEAR TIGHT CHLORITE STAINED FEW DRIPS
MUCK BAY NO.3
SHEAR CHLORITE STAINED, TIGHT, WET
SHEAR DISCONTINUOUS CHLORITE STAINED
DISCONTINUOUS JOINT W/ WHITE STAINING IN BASALT
SERIES OF PARALLEL JOINTS DISCONTINUOUS VERY WET JOINT
SEEP FLOWS 5GPM
SHEARS RELATIVELY TIGHT WITH BASALT INTRUSIONS
SHEAR, IRON STAINED TIGHT
DIORITE
SHEAR WITH CHLORITE STAINING, DRIPPY
BASALT DIKE 6" AT INVERT, 8" WIDE AT S.L.
DISCONTINUOUS JOINTS
BASALT DIKE UP TO 2 INCH WIDE, DARK GRAY BLOCKY
SHEAR TIGHT, THIN WHITE MINERALIZATION ALONG CONTACT
TRANSFORMER BAY NO.3
DISCONTINUOUS JOINTS, TIGHT
DISCONTINUOUS JOINTS TIGHT
MASSIVE QUARTZ DIORITE GNEISS
WITH NO STRONG
33+20
33+40
34+00
34+20
34+40
34+60
34+80
35+20
35+40
JOINT
JOINT, TIGHT
SHEAR WITH TRACE OF CREAM COLORED MYLONITE, DRY.
JOINT TIGHT WITH PARALLEL JOINTS
JOINTS TIGHT DISCONTINUOUS
JOINT TIGHT, DISCONTINUOUS
SHEAR ZONE 6 INCH WIDE WITH SEVERAL PARALLEL SHEARS CREAM COLORED MYLONITE
SEEP, 2/3 GPM
JOINTS, TIGHT DISCONTINUOUS
MASSIVE QUARTZ DIORITE GNEISS WITH NO PROMINENT JOINTING
JOINTS, TIGHT DISCONTINUOUS
BASALT DIKE, GRAY, BLOCKY
JOINTS TIGHT DISCONTINUOUS BASALT STRINGER
JOINT, TIGHT
SERIES OF DISCONTINUOUS JOINTS
SERIES OF DISCONTINUOUS JOINTS
SMALL BASALT DIKE
39+20



NOTE:
SEE FIGURE B-1 FOR LEGEND AND ABBREVIATIONS.

Revisions			
Symbol	Descriptions	Date	Approved

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LACHEL HANSEN & ASSOCIATES, INC.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

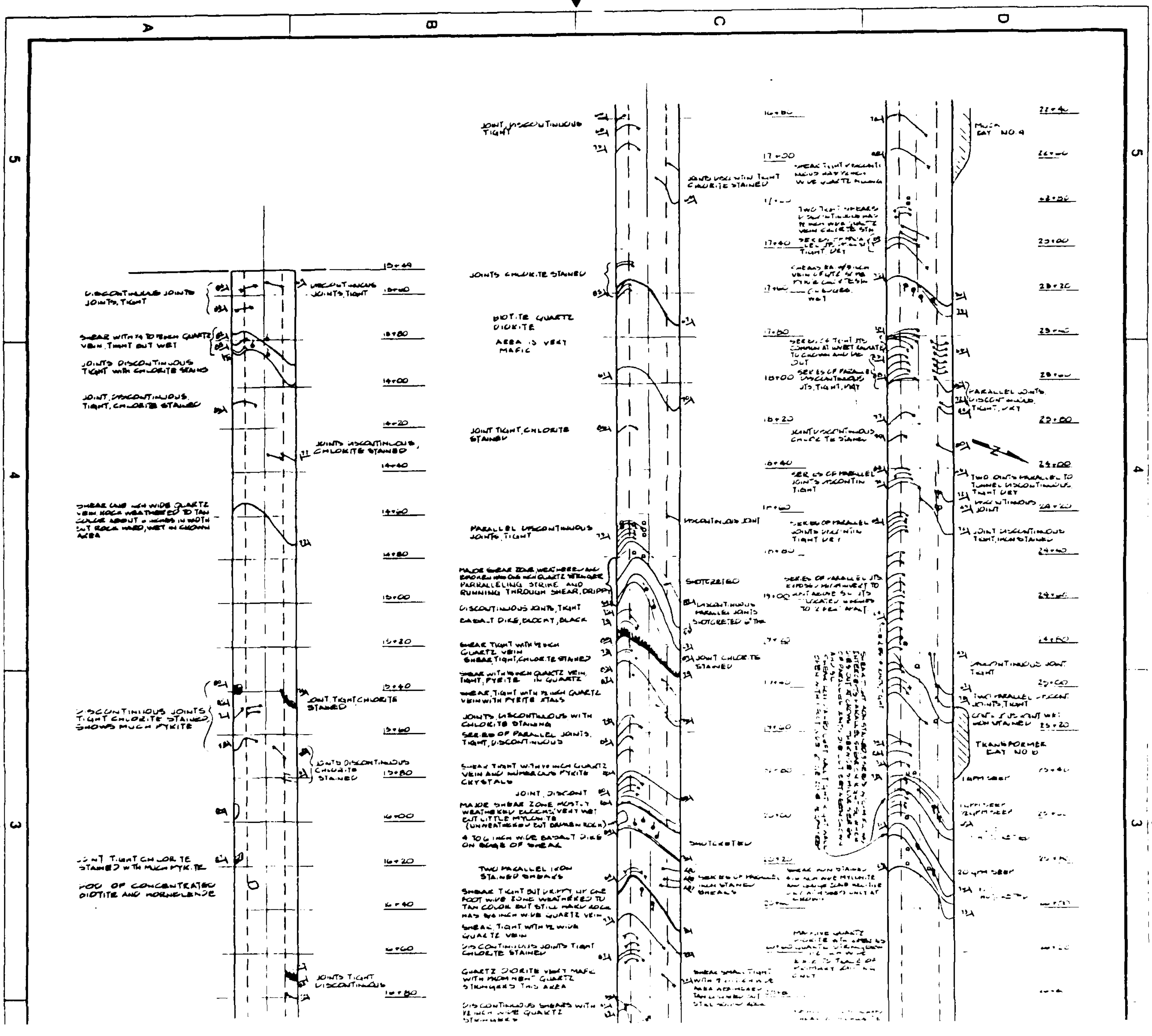
Designed by: JCB
Drawn by: JBT
Checked by:
Reviewed by: DJL
Approved by:

US Army Corps of Engineers

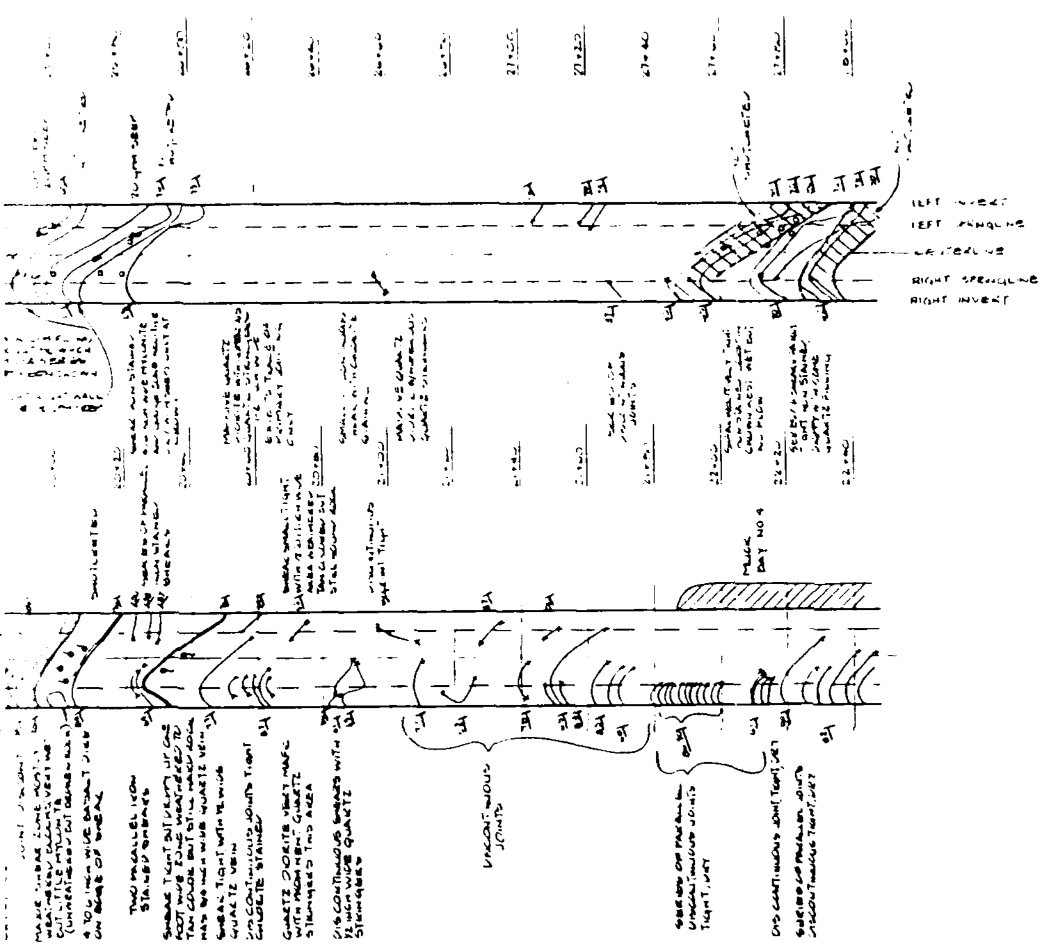
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1
POWER TUNNEL
STA. 28+00 TO 40+60
GEOLOGIC MAP

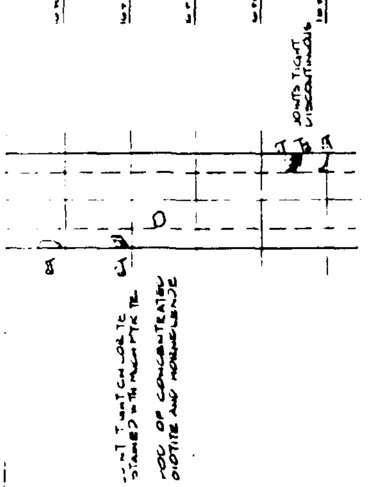
Scale: 1" = 20'-0"
Date: FEB 88
Drawing Code:
Sheet reference number:

Figure B-4



A
B
C
D
5
4
3
DISCONTINUOUS JOINTS JOINTS, TIGHT
DISCONTINUOUS JOINTS, TIGHT
SHEAR WITH 1/4 TO 1/2 INCH QUARTZ VEIN, TIGHT BUT WET
JOINTS DISCONTINUOUS TIGHT WITH CHLORITE STAINS
JOINT, DISCONTINUOUS, TIGHT, CHLORITE STAINED
JOINTS DISCONTINUOUS, CHLORITE STAINED
JOINT TIGHT CHLORITE STAINED
JOINTS DISCONTINUOUS CHLORITE STAINED
POD OF CONCENTRATED BIOTITE AND HORNBLENDE
JOINTS TIGHT DISCONTINUOUS
JOINTS CHLORITE STAINED
BIOTITE QUARTZ DIORITE
AREA IS VERY MAFIC
JOINT TIGHT, CHLORITE STAINED
PARALLEL DISCONTINUOUS JOINTS, TIGHT
DISCONTINUOUS JOINTS, TIGHT
BASALT DIKE, BLOCKY, BLACK
JOINT CHLORITE STAINED
SHOTCRETED
TWO PARALLEL IRON STAINED SHEARS
QUARTZ DIORITE VERY MAFIC WITH PROMINENT QUARTZ STRINGERS THIS AREA
TRANSFORMER BAY NO 10
MUCK BAY NO 9
PARALLEL JOINTS, DISCONTINUOUS, TIGHT, WET
JOINT DISCONTINUOUS TIGHT, IRON STAINED





NOTE:
SEE FIG B-1 FOR LEGEND AND ABBREVIATIONS

Revisions			
Symbol	Descriptions	Date	Approved

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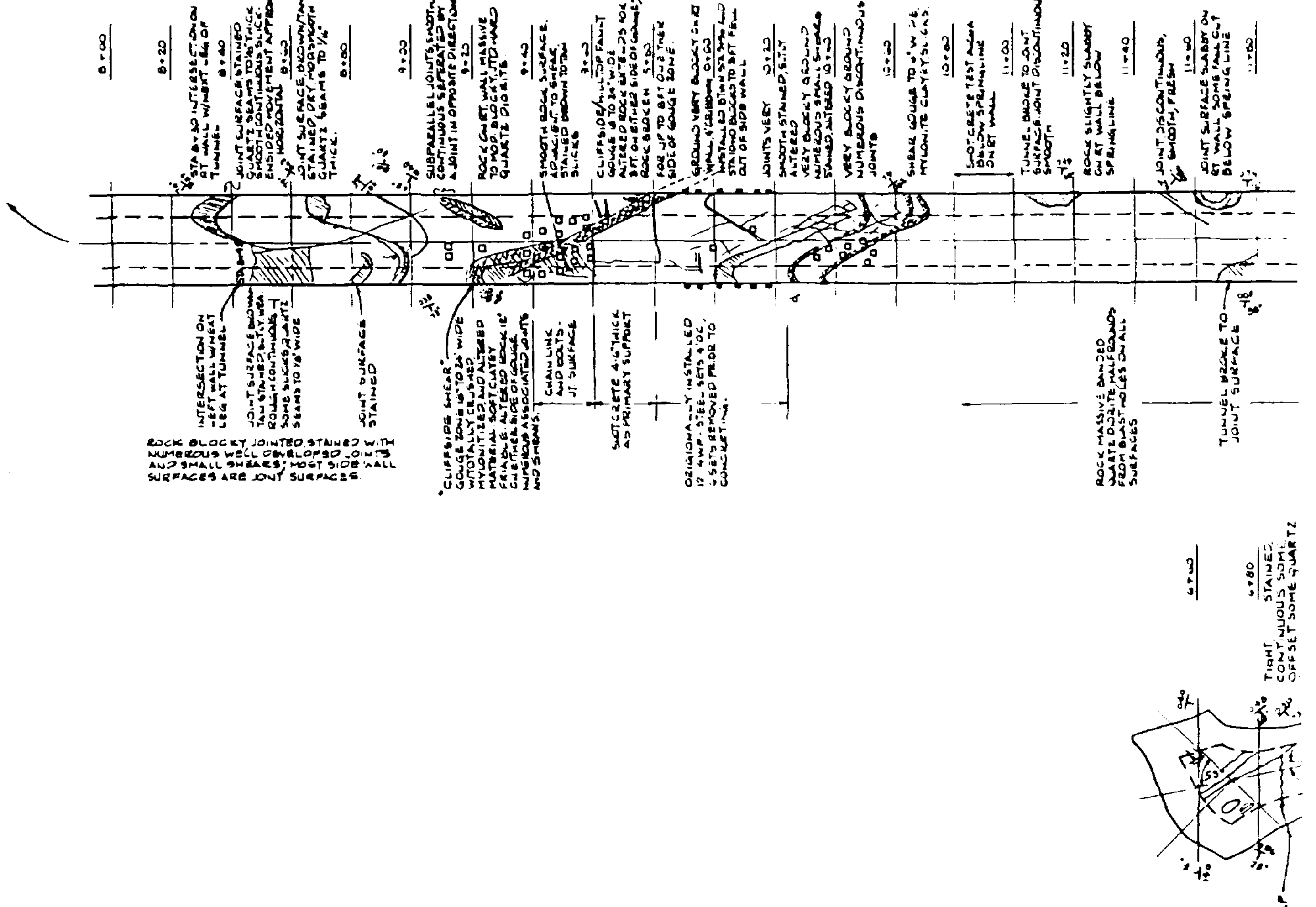
LACHEL HANSEN & ASSOCIATES, INC.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

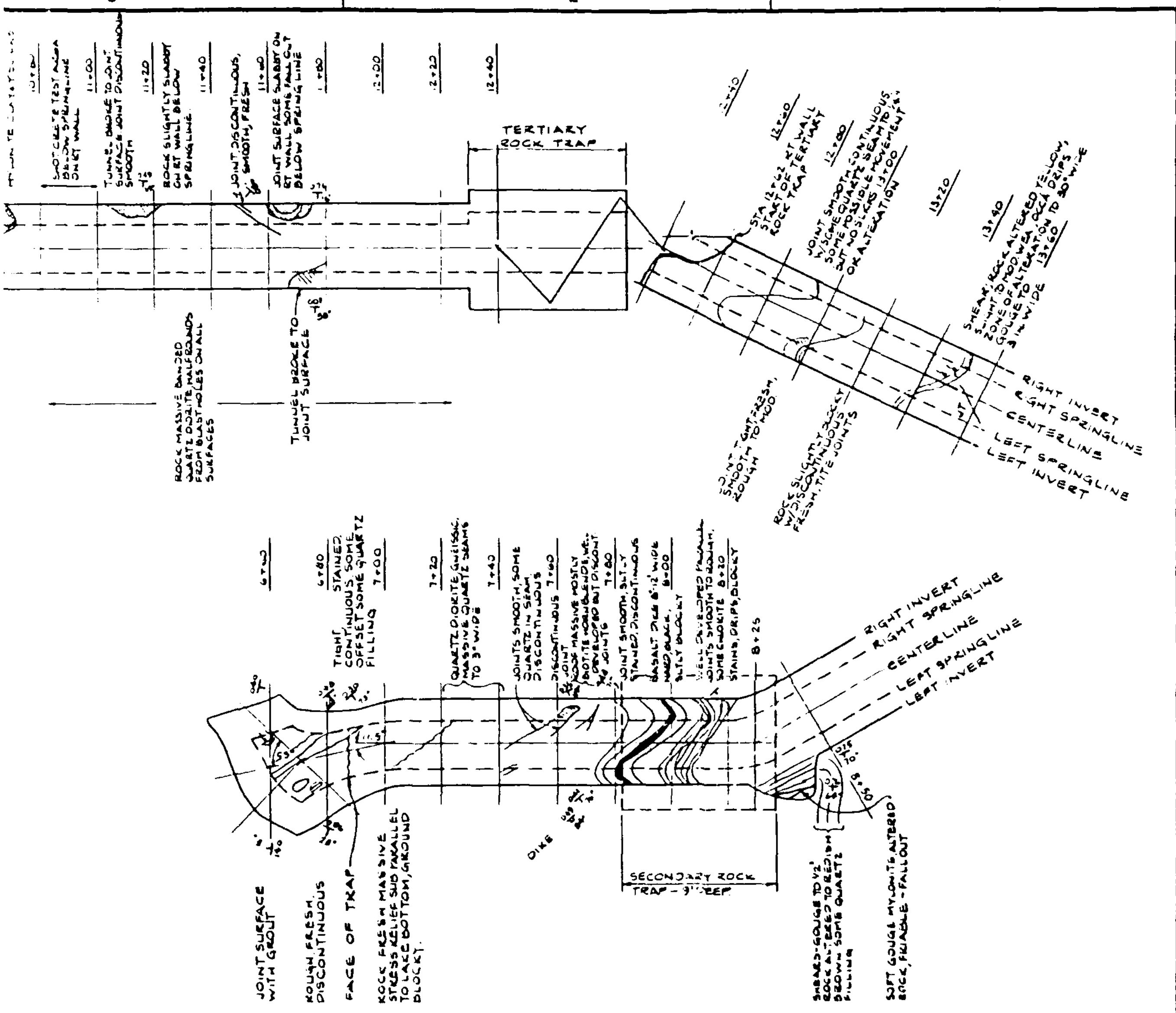
US Army Corps of Engineers

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1
POWER TUNNEL
STA. 13+49 TO 28+00
GEOLOGIC MAP

Designed by: JCB
Drawn by: JST
Checked by:
Reviewed by: DVL
Approved by:
Scale: 1" = 20'-0"
Date: FEB. 88
Drawing Code:
Sheet reference number:
Figure B-3



NOTE:
SEE FIG B-1 FOR LE



Revisions			
Symbol	Descriptions	Date	Approved

LACHEL HANSEN & ASSOCIATES
ANCHORAGE, AK.
GOLDEN, CO.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

Designed by: D. J. L.

Drawn by: JST.

Checked by:

Reviewed by:

Approved by: D. J. Lachel

US Army Corps of Engineers

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE
POWER TUNNEL & LAKE TAP
STA. 13 +60 TO 6 +60
GEOLOGIC MAP

Scale: 1" = 20'-0"

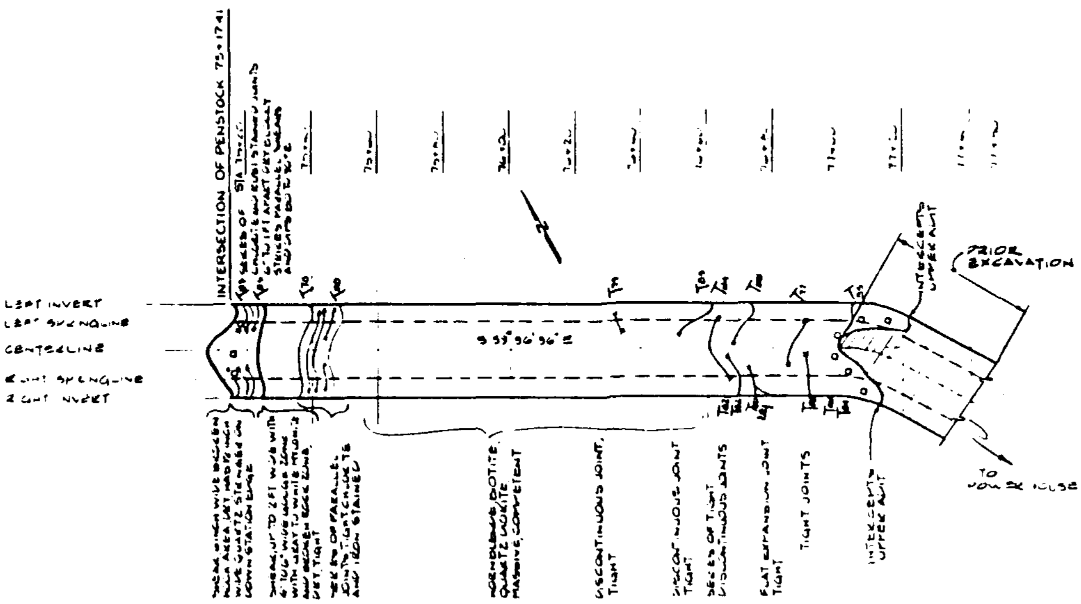
Date:

Drawing Code:

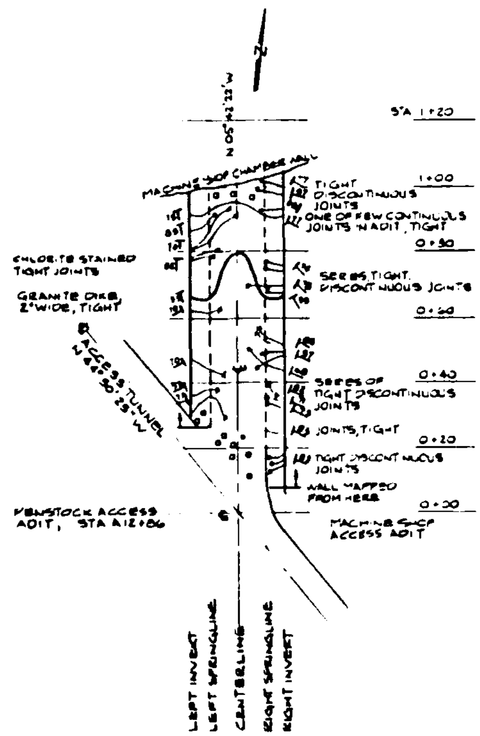
Sheet reference number:

FIGURE B-6

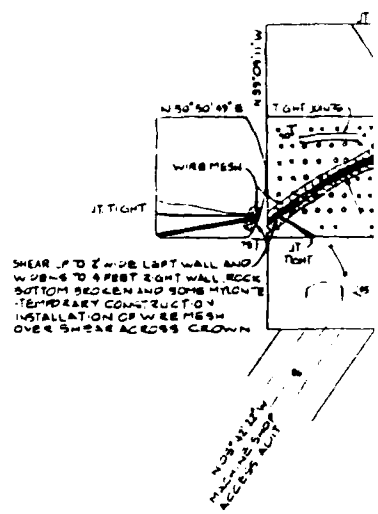
NOTE:
SEE FIG B-1 FOR LEGEND AND ABBREVIATIONS



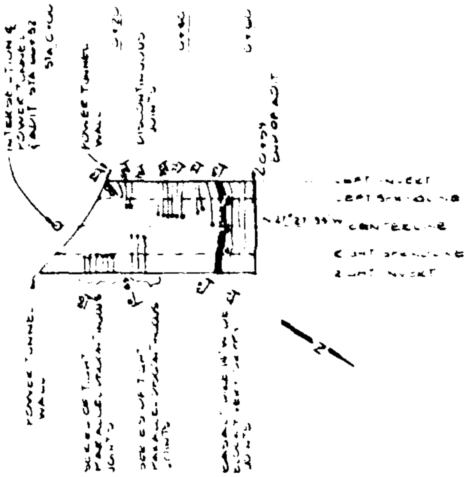
PENSTOCK EXTENSION



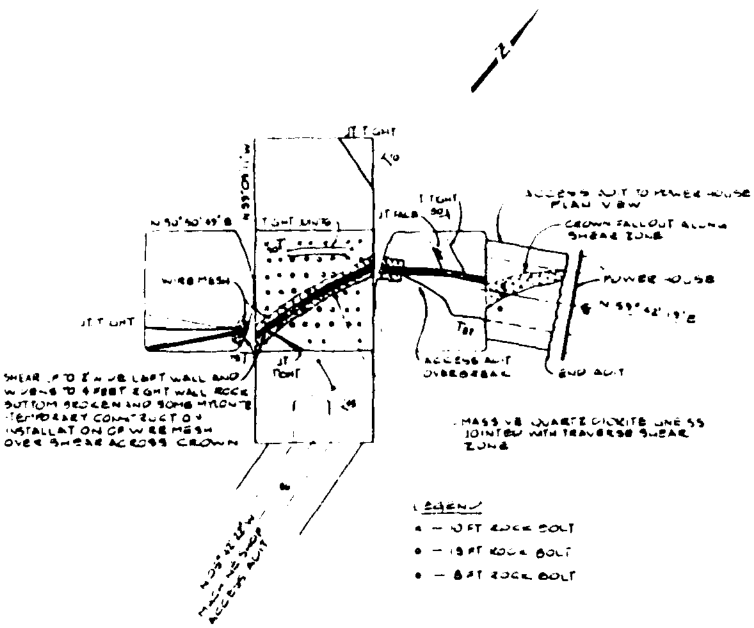
MACHINE SHOP ADIT



MACHINE SHOP C



SURGE TANK ADIT



MACHINE SHOP CHAMBER

NOTE:
SEE FIG B FOR LEGEND AND ABBREVIATIONS

Symbol	Revisions Descriptions	Date	Approved

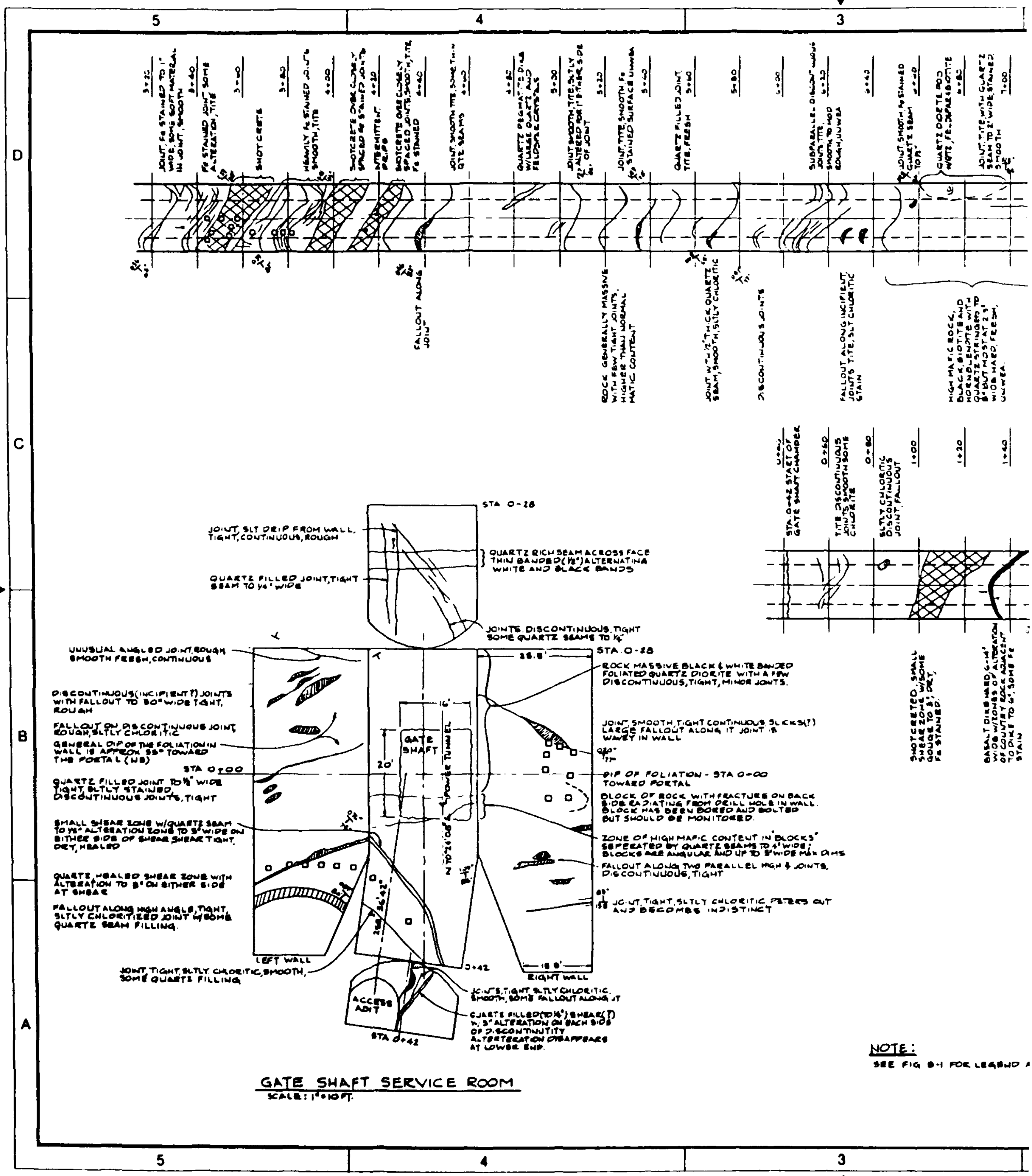
POLARCONSULT ALASKA, INC.
LACHEL HANSEN & ASSOCIATES, INC.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

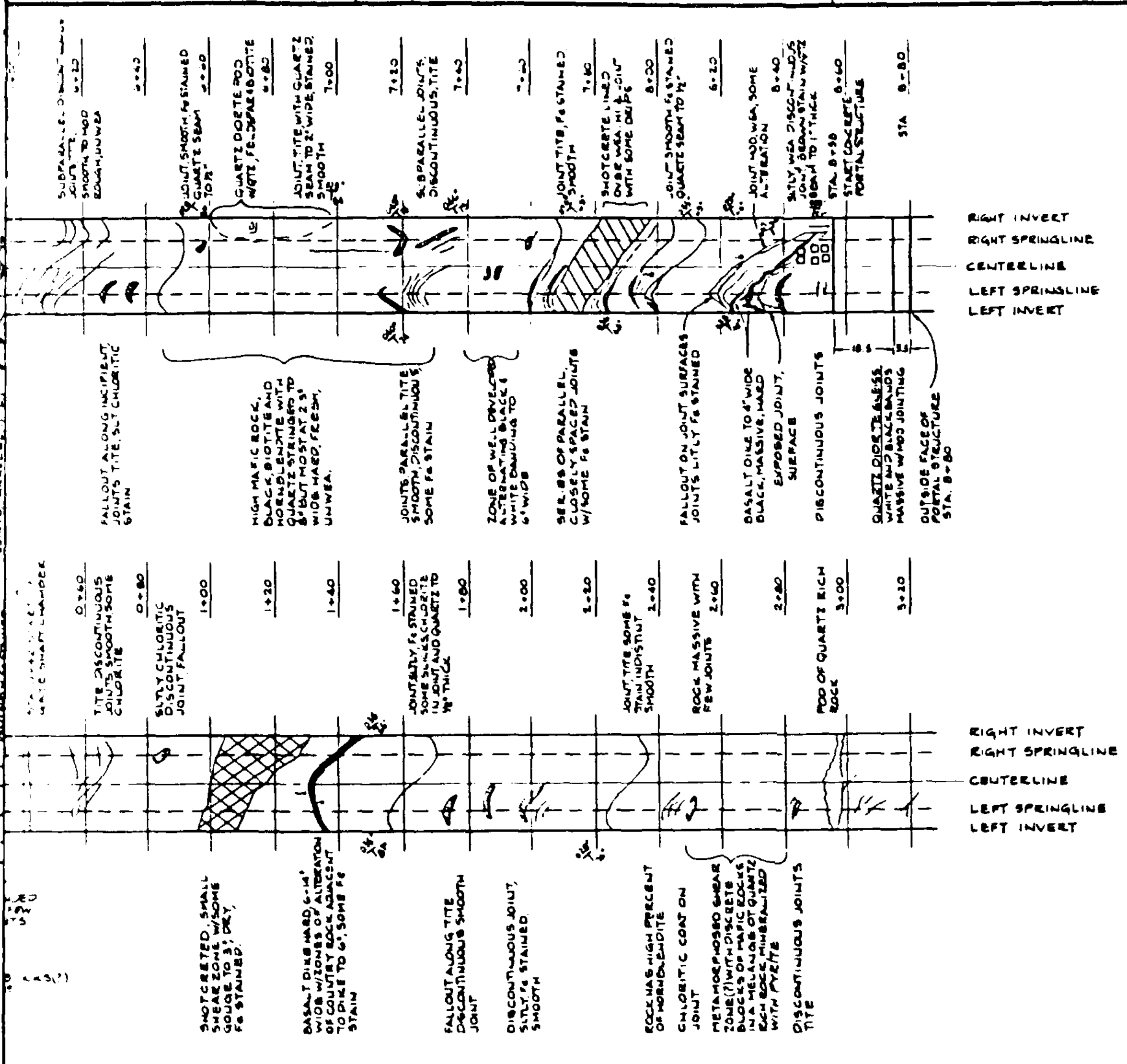
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE PHASE 1
SURGE TANK ADIT,
MACHINE SHOP CHAMBER AND
ADIT. PENSTOCK EXTENSION.
GEOLOGIC MAP

Designed by:	JCB
Drawn by:	JST
Checked by:	
Reviewed by:	DJL
Approved by:	
Scale:	1" = 20' 0"
Date:	FEB 88
Drawing Code	
Sheet reference number:	

Figure B-7



5
4
3
D
C
B
A
STA 0-28
JOINT, SLT DRIP FROM WALL, TIGHT, CONTINUOUS, ROUGH
QUARTZ RICH SEAM ACROSS FACE THIN BANDED (1/2") ALTERNATING WHITE AND BLACK BANDS
QUARTZ FILLED JOINT, TIGHT SEAM TO 1/4" WIDE
JOINTS DISCONTINUOUS, TIGHT SOME QUARTZ SEAMS TO 1/4"
UNUSUAL ANGLED JOINT, ROUGH, SMOOTH FRESH, CONTINUOUS
STA. 0-28
ROCK MASSIVE BLACK & WHITE BANDED FOLIATED QUARTZ DIORITE WITH A FEW DISCONTINUOUS, TIGHT, MINOR JOINTS.
DISCONTINUOUS (INCIPIENT?) JOINTS WITH FALLOUT TO 30" WIDE TIGHT, ROUGH
FALLOUT ON DISCONTINUOUS JOINT ROUGH, SLTLY CHLORITIC
JOINT, SMOOTH, TIGHT CONTINUOUS SLICKS(?) LARGE FALLOUT ALONG IT JOINT IS WAVEY IN WALL
GENERAL DIP OF THE FOLIATION IN WALL IS APPROX 35° TOWARD THE PORTAL (NE)
GATE SHAFT
POWER TUNNEL
STA 0+00
DIP OF FOLIATION - STA 0+00 TOWARD PORTAL
QUARTZ FILLED JOINT TO 1/2" WIDE TIGHT, SLTLY STAINED, DISCONTINUOUS JOINTS, TIGHT
BLOCK OF ROCK WITH FRACTURE ON BACK SIDE RADIATING FROM DRILL HOLE IN WALL. BLOCK HAS BEEN BORED AND BOLTED BUT SHOULD BE MONITORED.
SMALL SHEAR ZONE W/QUARTZ SEAM TO 1/2" ALTERATION ZONE TO 3" WIDE ON EITHER SIDE OF SHEAR SHEAR TIGHT, DRY, HEALED
ZONE OF HIGH MAFIC CONTENT IN "BLOCKS" SEPERATED BY QUARTZ SEAMS TO 1" WIDE; BLOCKS ARE ANGULAR AND UP TO 3' WIDE MAX DIMS
FALLOUT ALONG TWO PARALLEL HIGH ∠ JOINTS, DISCONTINUOUS, TIGHT
QUARTZ HEALED SHEAR ZONE WITH ALTERATION TO 3" ON EITHER SIDE AT SHEAR
JOINT, TIGHT, SLTLY CHLORITIC, PETERS OUT AND BECOMES INDISTINCT
FALLOUT ALONG HIGH ANGLE, TIGHT, SLTLY CHLORITIZED JOINT W/SOME QUARTZ SEAM FILLING.
LEFT WALL
RIGHT WALL
0+42
JOINT, TIGHT, SLTLY CHLORITIC, SMOOTH, SOME QUARTZ FILLING
JOINTS, TIGHT, SLTLY CHLORITIC, SMOOTH, SOME FALLOUT ALONG IT
ACCESS ADIT
QUARTZ FILLED (TO 1/4") SHEAR(?) W/ 3" ALTERATION ON EACH SIDE OF DISCONTINUITY ALTERATION DISAPPEARS AT LOWER END.
STA 0+42
NOTE:
SEE FIG B-1 FOR LEGEND
GATE SHAFT SERVICE ROOM
SCALE: 1"=10 FT.



NOTE:
SEE FIG B-1 FOR LEGEND AND ABBREVIATIONS

Revisions			
Symbol	Descriptions	Date	Approved

LACHEL HANSEN & ASSOCIATES
ANCHORAGE, AK.
GOLDEN, CO

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

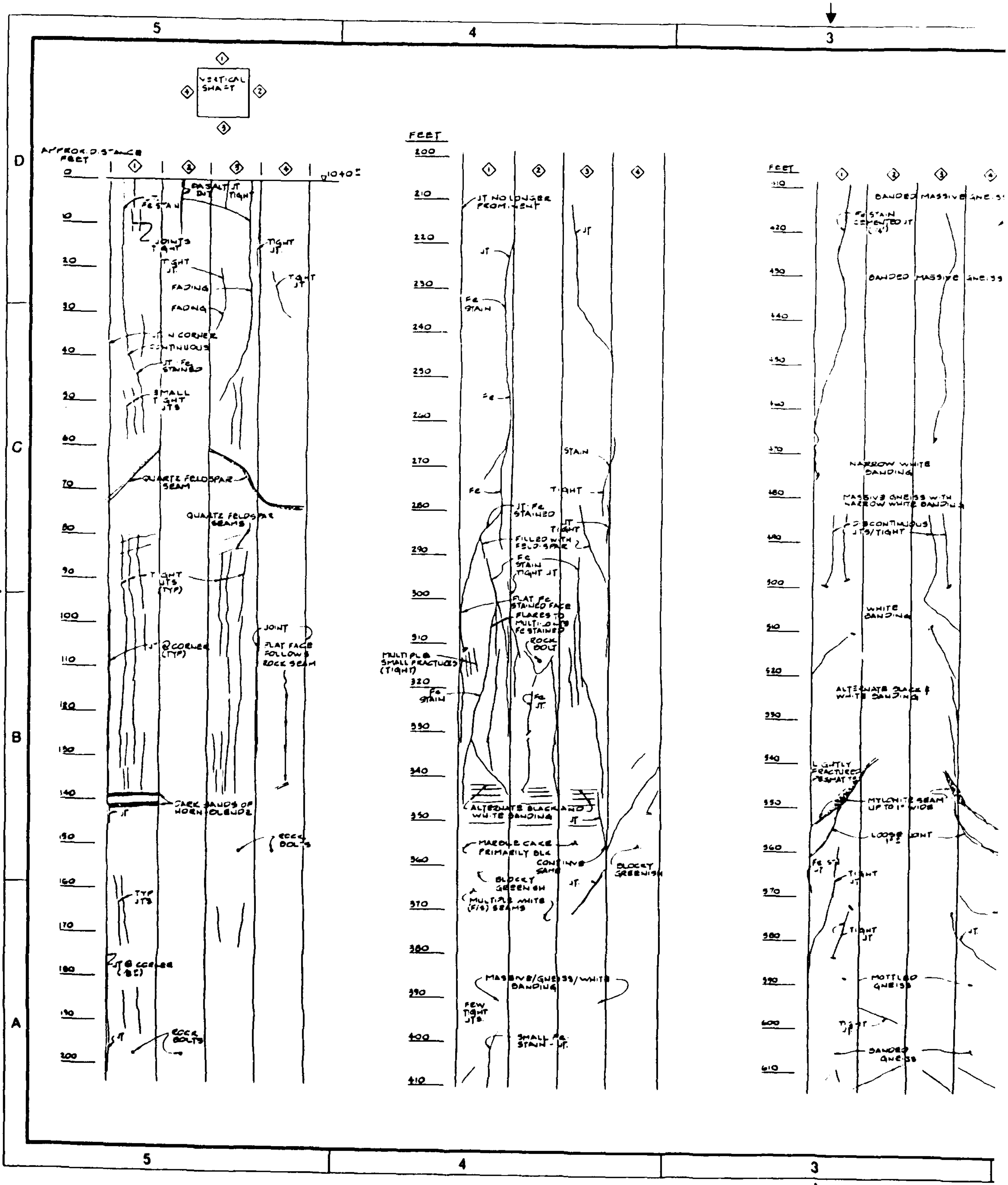
Designed by: D.J.L.
Drawn by: JST
Checked by:
Reviewed by:
Approved by:

US Army Corps of Engineers

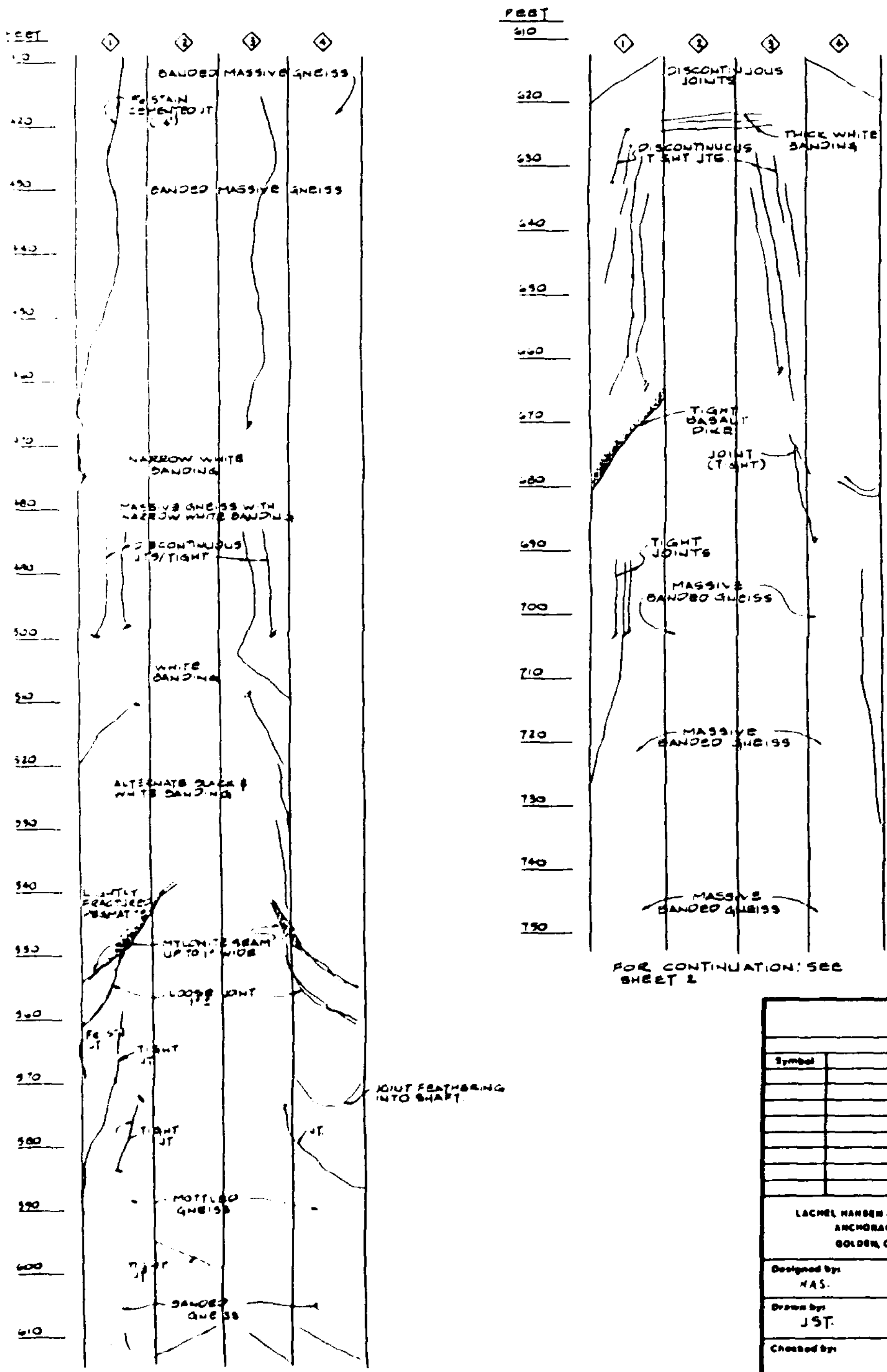
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPMENT
CRATER LAKE
UPPER ACCESS TUNNEL & GATE SHAFT SERVICE ROOM GEOLOGIC MAP

Scale: 1" = 20'-0"
Date:
Drawing Code:
Sheet reference number:

FIGURE B-8



VERTICAL SHAFT
APPROX. DISTANCE FEET
FEET
FE STAIN
JOINTS TIGHT
TIGHT JT.
FADING
JT IN CORNER
CONTINUOUS
JT. Fe STAINED
SMALL TIGHT JTS
QUARTZ FELDSPAR SEAM
QUARTZ FELDSPAR SEAMS
TIGHT JTS (TYP)
JT @ CORNER (TYP)
JOINT
FLAT FACE FOLLOWS ROCK SEAM
DARK BANDS OF HORNBLENDE
ROCK BOLTS
TYP JTS
JT @ CORNER (BI)
JT NO LONGER PROMINENT
Fe STAIN
STAIN
TIGHT
JT. Fe STAINED
FILLED WITH FELDSPAR
FLAT Fe STAINED FACE
FLARES TO MULTI-JOINTS Fe STAINED
ROCK BOLT
MULTIPLE SMALL FRACTURES (TIGHT)
ALTERNATE BLACK AND WHITE BANDING
MARBLE CAKE PRIMARILY BLK
CONTINUOUS SEAM
BLOCKY GREENISH
MULTIPLE WHITE (F/S) SEAMS
MASSIVE/GNEISS/WHITE BANDING
FEW TIGHT JTS.
SMALL Fe STAIN - JT.
BANDED MASSIVE GNEISS
Fe STAIN CEMENTED JT
NARROW WHITE BANDING
MASSIVE GNEISS WITH NARROW WHITE BANDING
DISCONTINUOUS JTS/TIGHT
WHITE BANDING
ALTERNATE BLACK & WHITE BANDING
LIGHTLY FRACTURED
MYLONITE SEAM UP TO 1" WIDE
LOOSE JOINT
TIGHT JT
MOTTLED GNEISS
BANDED GNEISS



Symbol	Descriptions	Date	Approved

Revisions

LACHEL HANSEN & ASSOCIATES
ANCHORAGE, AK.
GOLDEN, CO.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

US Army Corps of Engineers

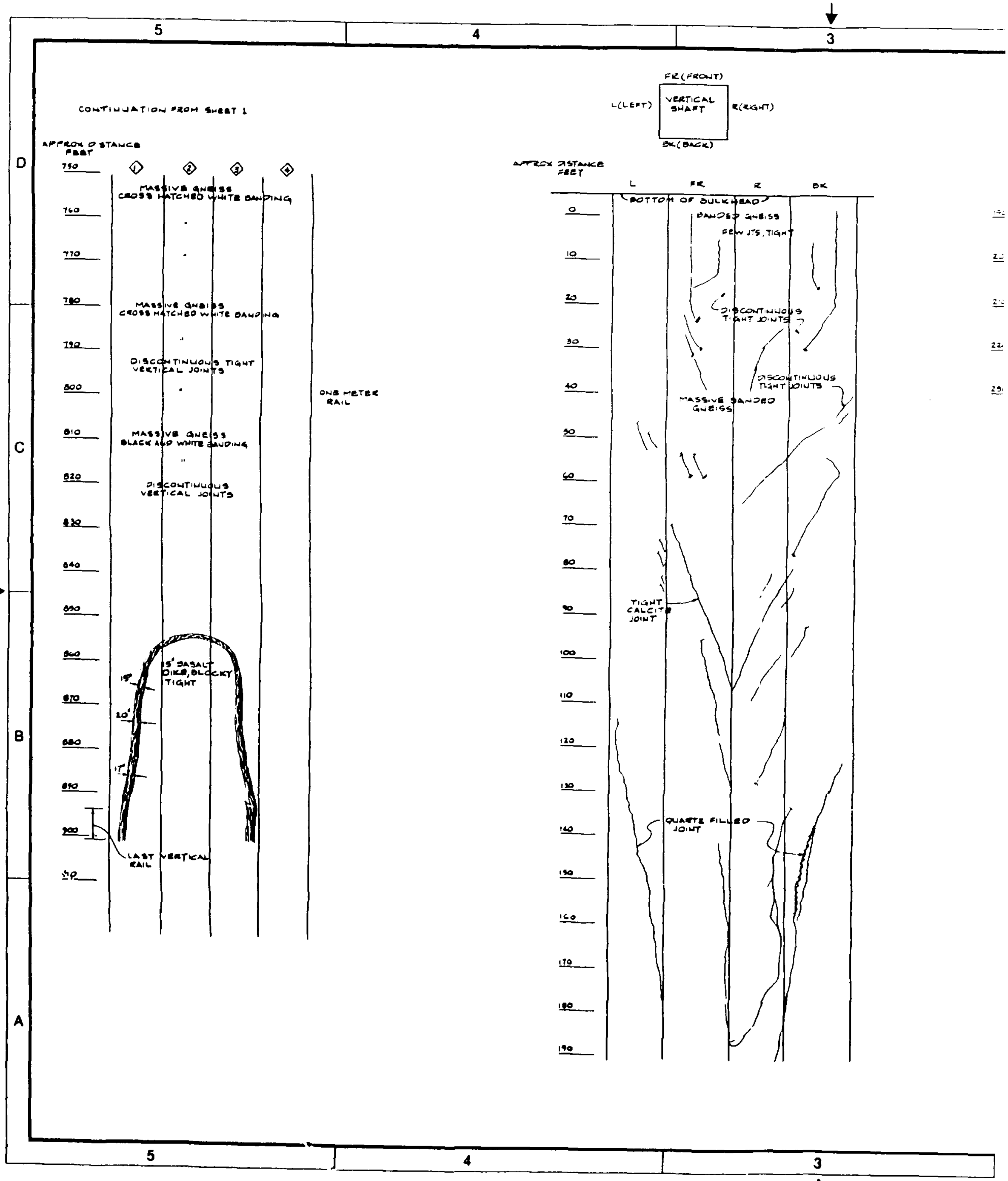
SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPEMENT
CRATER LAKE

SURGE SHAFT
0 TO 750 FT.

Designed by: HAS.
Drawn by: JST.
Checked by:
Reviewed by:
Approved by: D. J. [illegible]

Scale: VERT. 1" = 10'
Date:
Drawing Code:
Sheet reference number:

FIGURE B-9



CONTINUATION FROM SHEET 1
APPROX DISTANCE FEET
750
760
770
780
790
800
810
820
830
840
850
860
870
880
890
900
910
1
2
3
4
MASSIVE GNEISS CROSS HATCHED WHITE BANDING
MASSIVE GNEISS CROSS HATCHED WHITE BANDING
DISCONTINUOUS TIGHT VERTICAL JOINTS
MASSIVE GNEISS BLACK AND WHITE BANDING
DISCONTINUOUS VERTICAL JOINTS
ONE METER RAIL
5' BASALT DIKE, BLOCKY TIGHT
15°
20°
17°
LAST VERTICAL RAIL
FR (FRONT)
L (LEFT)
VERTICAL SHAFT
R (RIGHT)
BK (BACK)
APPROX DISTANCE FEET
L
FR
R
BK
BOTTOM OF BULKHEAD
BANDED GNEISS
FEW JTS, TIGHT
DISCONTINUOUS TIGHT JOINTS
DISCONTINUOUS TIGHT JOINTS
MASSIVE BANDED GNEISS
TIGHT CALCITE JOINT
QUARTZ FILLED JOINT
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
5
4
3
D
C
B
A

Revisions			
Symbol	Descriptions	Date	Approved

LACHEL HANSEN & ASSOCIATES
ANCHORAGE, AK.
GOLDEN, CO.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

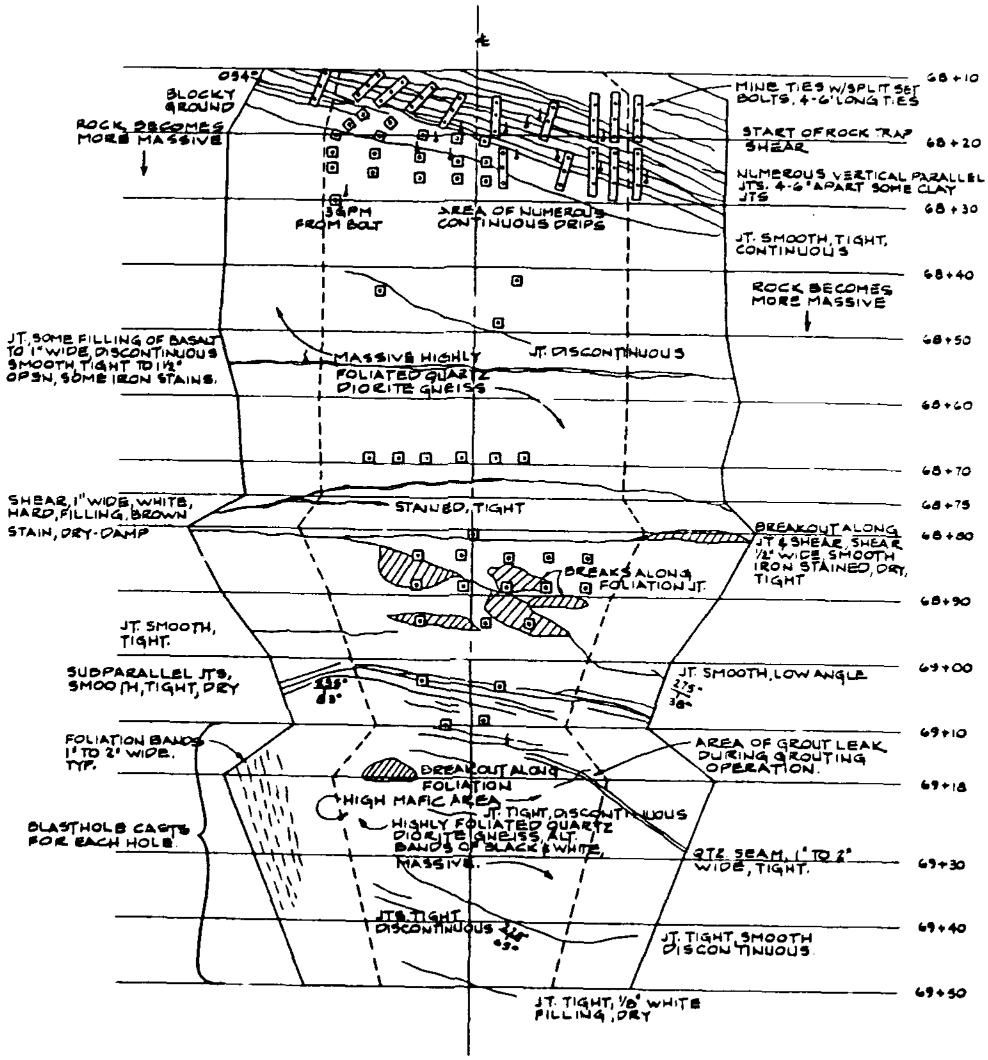
US Army Corps of Engineers

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPEMENT
CRATER LAKE
SURGE SHAFT
750 TO 900 FT.
GATE SHAFT 0 TO 230 FT.

Designed by: H.A.S
Drawn by: J.S.T.
Checked by:
Reviewed by:
Approved by: D.J.L.

Scale: VERT. 1" = 10'
Date:
Drawing Code:
Sheet reference number:

FIGURE 8-10



094°
BLOCKY GROUND
ROCK BECOMES MORE MASSIVE
MINE TIES W/SPLIT SET BOLTS, 4-6' LONG TIES
START OF ROCK TRAP SHEAR
NUMEROUS VERTICAL PARALLEL JTS. 4-6' APART SOME CLAY JTS
3GPM FROM BOLT
AREA OF NUMEROUS CONTINUOUS DRIPS
JT. SMOOTH, TIGHT, CONTINUOUS
ROCK BECOMES MORE MASSIVE
JT. SOME FILLING OF BASALT TO 1" WIDE, DISCONTINUOUS SMOOTH, TIGHT TO 1/2" OPEN, SOME IRON STAINS.
MASSIVE HIGHLY FOLIATED QUARTZ DIORITE GNEISS
JT. DISCONTINUOUS
SHEAR, 1" WIDE, WHITE, HARD, FILLING, BROWN STAIN, DRY-DAMP
STAINED, TIGHT
BREAKOUT ALONG JT & SHEAR, SHEAR 1/2" WIDE SMOOTH IRON STAINED, DRY, TIGHT
BREAKS ALONG FOLIATION JT.
JT. SMOOTH, TIGHT.
SUBPARALLEL JTS, SMOOTH, TIGHT, DRY
JT. SMOOTH, LOW ANGLE
FOLIATION BANDS 1" TO 2" WIDE. TYP.
AREA OF GROUT LEAK DURING GROUTING OPERATION.
BREAKOUT ALONG FOLIATION
HIGH MAFIC AREA
JT. TIGHT, DISCONTINUOUS
BLASTHOLE CASTS FOR EACH HOLE
HIGHLY FOLIATED QUARTZ DIORITE GNEISS, ALT. BANDS OF BLACK & WHITE, MASSIVE.
QTZ SEAM, 1" TO 2" WIDE, TIGHT.
JTS TIGHT DISCONTINUOUS
JT. TIGHT SMOOTH DISCONTINUOUS
JT. TIGHT, 1/8" WHITE FILLING, DRY
68+10
68+20
68+30
68+40
68+50
68+60
68+70
68+75
68+80
68+90
69+00
69+10
69+18
69+30
69+40
69+50

Revisions			
Symbol	Descriptions	Date	Approved

LACHEL HANSEN & ASSOCIATES
ANCHORAGE, AK.
GOLDEN, CO.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

US Army Corps of Engineers

SNETTISHAM PROJECT, ALASKA
SECOND STAGE DEVELOPEMENT
CRATER LAKE
PENSTOCK PLUG AREA

Designed by: JJL
Drawn by: JST.
Checked by:
Reviewed by:
Approved by: D J Lachel

Scale: 1" = 10'
Date:
Drawing Code:
Sheet reference number:

FIGURE B-11

APPENDIX C

PHOTOGRAPHS

Photo 1: Snettisham fjord with Speel River
coming in from left

Photo 2: Drilling of the Crater Lake tunnel portal

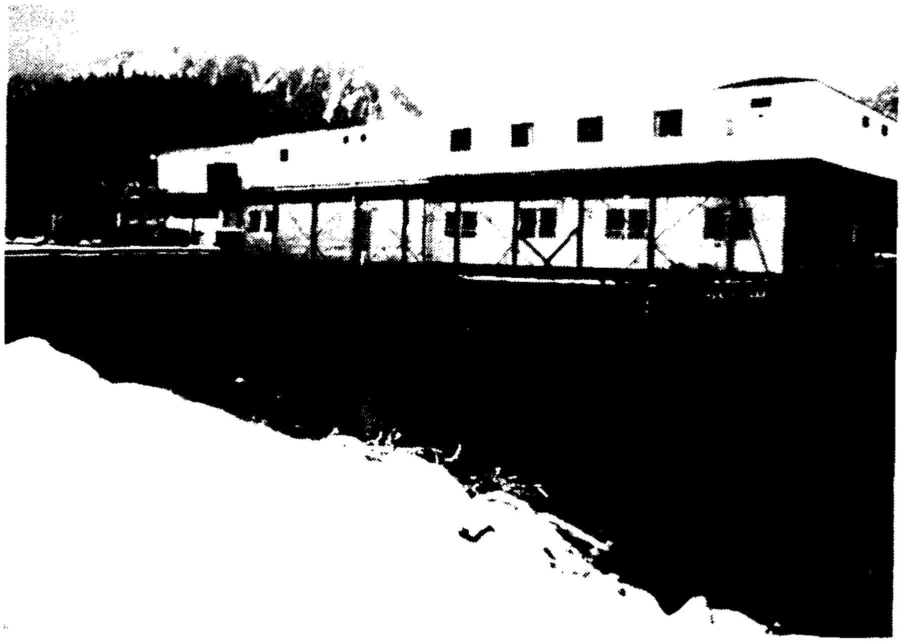


Photo 3: South Coast, Inc. barge-mounted camp facilities
which were floated to Snettisham small boat harbor

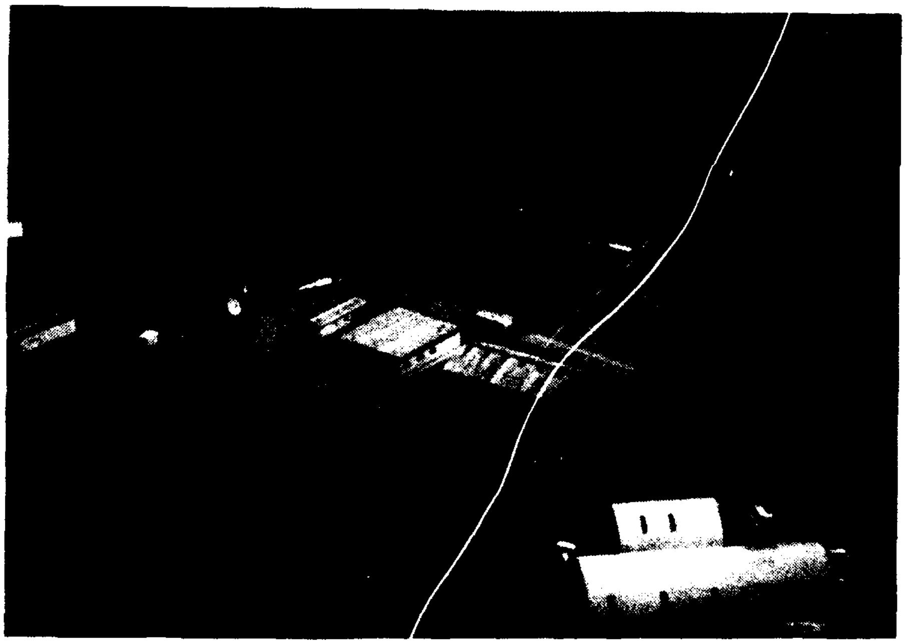


Photo 4: Pacific Ventures construction camp and staging area

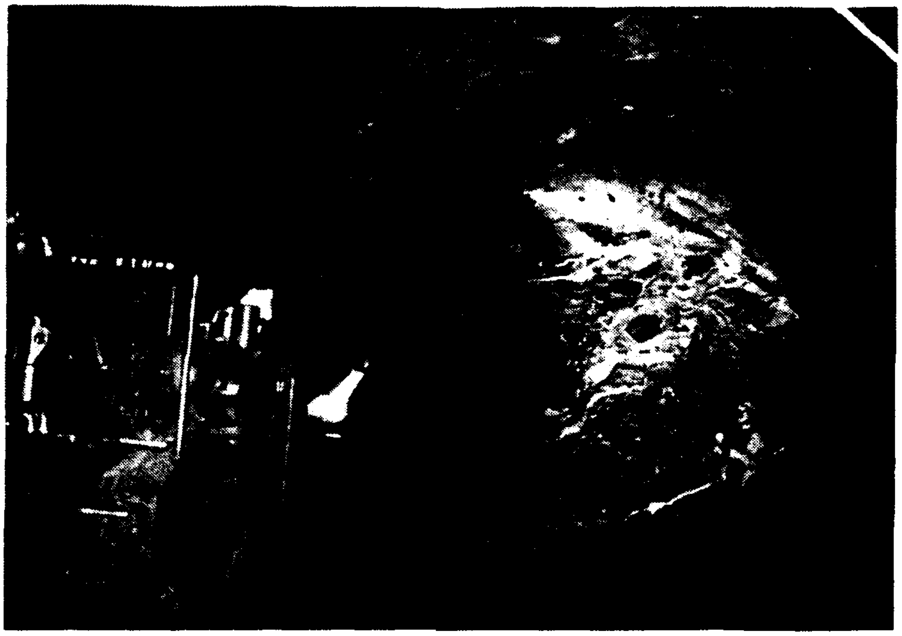


Photo 5: Hydraulic drill jumbo and Crater Lake penstock tunnel face; note gneissic banding in rock

Photo 6: Crater Lake access tunnel with avalance shed portal structure

Photo 7: Scaling the crown in the Crater Lake power tunnel

Photo 8: Helicopter departing surge tank collar area

Photo 9: South Coast, Inc. ST-8 Scooptrams used for mucking the Crater Lake power tunnel

Photo 10: Shotcrete application in Crater Lake power tunnel

Photo 11: Exhausting blast smoke from Gate Shaft service room adit

Photo 12: Gate Shaft service room adit portal

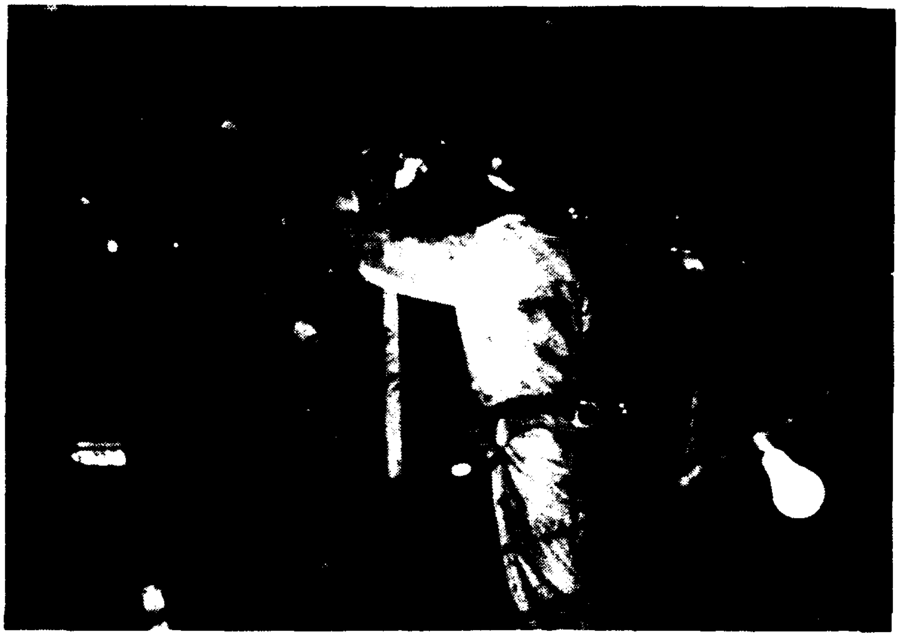


Photo 13: Grouting of the Crater Lake tap plug area 12 ft from the bottom of the lake under 210 ft of water

Photo 14: Pumps and set-up during consolidation grouting in the final tunnel plug area

Photo 15: Contractor-designed grouting manifold which permitted simultaneous grouting of six holes in the lake tap plug area

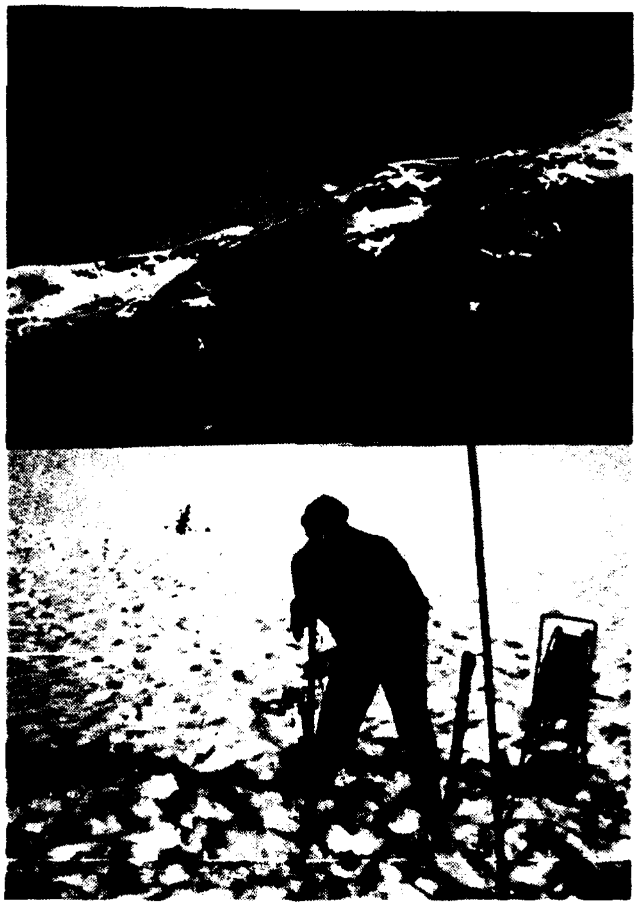


Photo 16: Sounding the bottom of the lake through the ice prior to the underwater lake tap

Photo 17: Norweigan Laketap Consultant, Finn Kvingen on top of ice plug upstream of slide gate prior to plug completion

Photo 18: Firing the final round of the Crater Lake underwater lake tap from the gate shaft service room

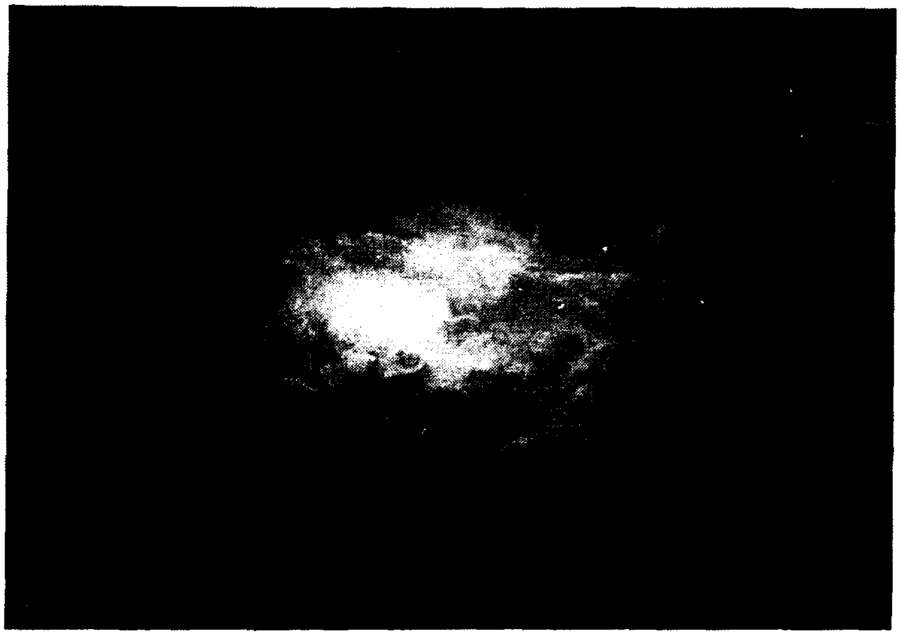


Photo 19: Bubbles in Crater Lake following lake tap blast

Photo 20: Instrument recorders of piezometers monitoring water pressures in lake tap and power tunnel area

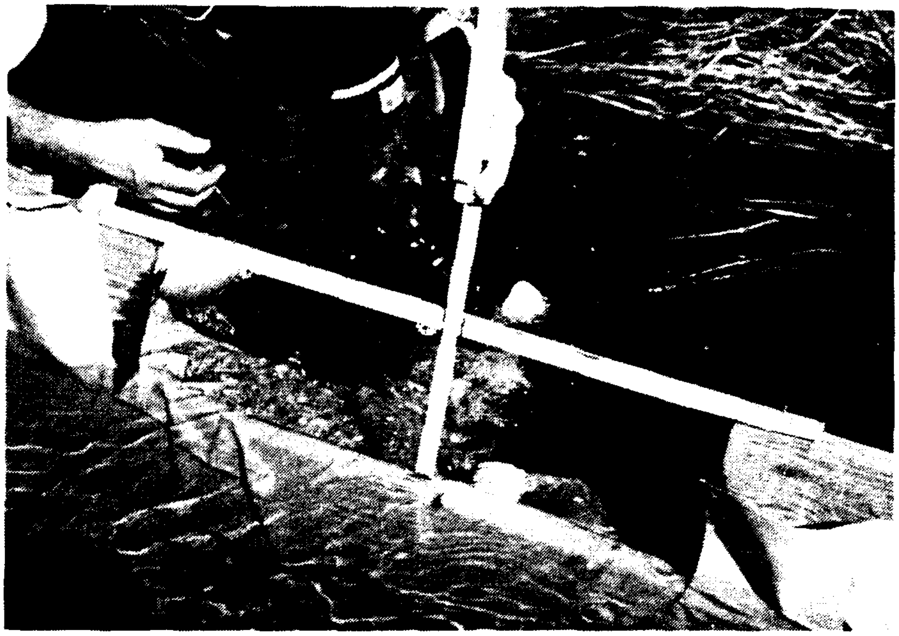


Photo 21: Monitoring streamflow wiers during initial filling of the Crater Lake power tunnel

Photo 22: Crater Lake access tunnel with avalanche shed portal structure

APPENDIX D

HYDROGRAPHIC SURVEILLANCE FOR TUNNEL FILLING

APPENDIX D - HYDROGRAPHIC SURVEILLANCE

INTRODUCTION

To obtain an idea of where leakage might occur during the filling of the power tunnel, L&A personnel physically walked the ground surface immediately above the area of the penstock and power tunnel up to the location of the surge tank on 21 and 22 November 1988. This area has the least amount of rock cover, and the surveillance area covered that portion of the mountain with surface elevations lying at or below the design elevation of Crater Lake (1,020 ft).

This work was performed by Mr. Harry Steeves and Dr. Dwayne Piepenburg at the direction of the Alaska District of the Corps of Engineers under Title II contract.

FIELD RECONAISSANCE

The surface area above the penstock/power tunnel alignment upstream of the surge tank was inspected and logged to establish the location of possible leaks, as well as to estimate their probable drainage routes. The exterior expression of faults and jointing was approximated on an aerial photograph, and the possible drainage routes from the location of the surge tank and below were mapped on an aerial photo.

The surface expression of the faulting in this area is shown on Figure D-1. The faulting orientation is typical of that found throughout the project, and tends to verify the assumed projections of faults shown on the penstock profile drawings of the contract drawings.

The alignment of the penstock/power tunnel was approximated on the ground surface by locating DH-115 and the top of the Crater Lake surge shaft. These both lie on the centerline of the tunnel.

The surface expression of a fault appears at the ground surface adjacent to the surge shaft roof. The affected width is probably as much as 100 ft. It appears likely that this area could be the extension of the faulted/broken area just upstream of the tunnel plug. The penstock profile suggests this extension also.

At least four parallel faults surface on the mountainside downhill from the surge tank area, and all serve as natural water collectors and flow paths.

There are four possible routes for surface flow from the area investigated. The two flow paths that are felt to be the most likely are designated "B" and "C" on Fig. D-1. The path designated "B" serves as the primary drainage for the area, and incorporates flow from the majority of the contributing fault lines. "C" drains a smaller area, but includes a spring from under the tailings of the Long Lake surge adit excavation. This spring may drain a considerable area east of the power tunnel alignment.

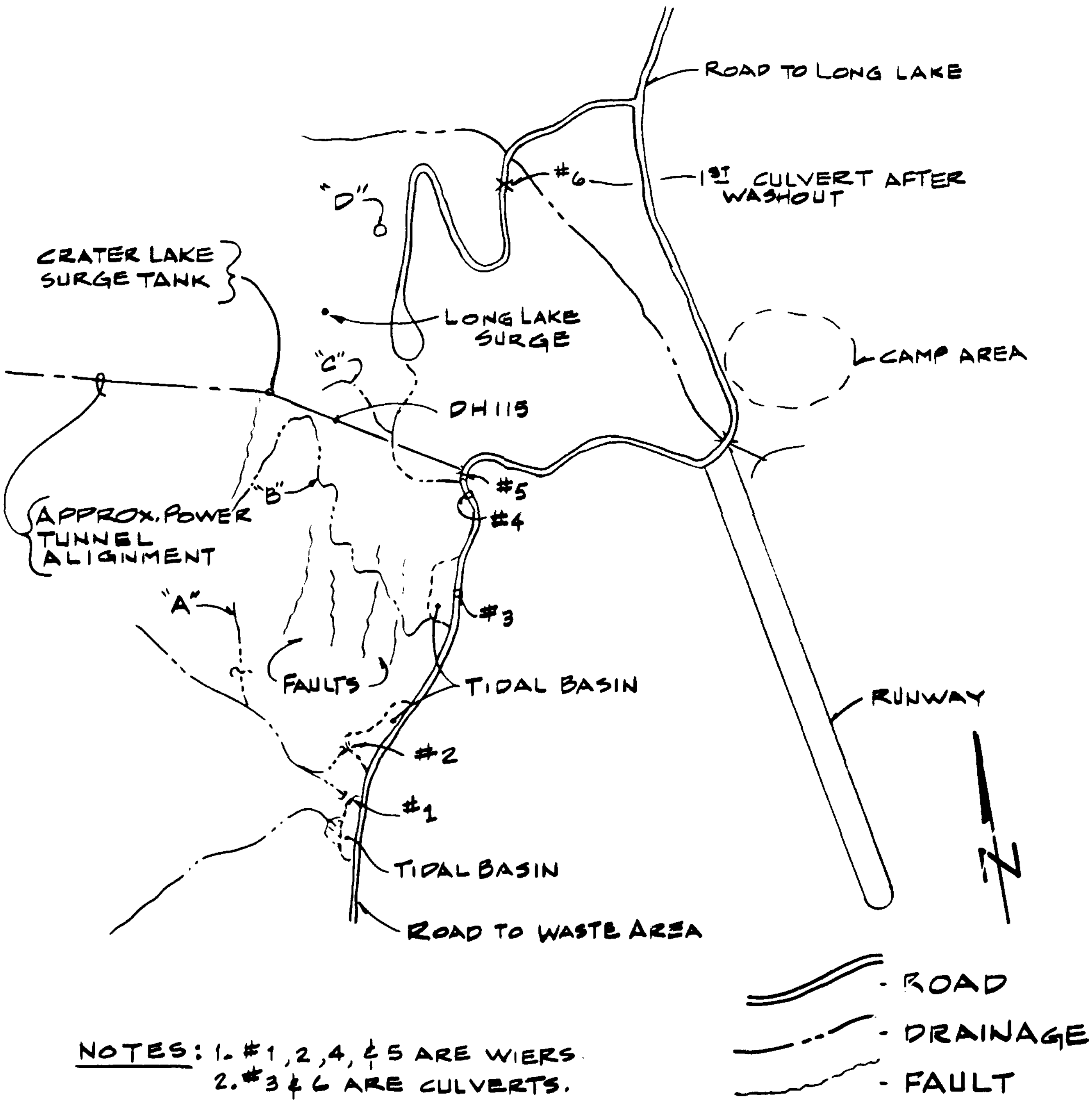
The area designated "D" is not likely to receive any leakage flow from the tunnel, but, for completeness, all flow from this area (other than any which goes to the spring flowing to path "C") will be channeled through the culvert designated as #6. Flow path "A" will catch any leakage not caught by "B".

METHODS ESTABLISHED TO MEASURE FLOW

Six monitoring locations are proposed to record ongoing flows from the hillside where high-pressure water may exit when the power tunnel is filled. These are shown on Figure D-1. Two monitoring locations are wiers, and four are culverts. Figure D-2 shows the form which will be used to record flow data, and Figure D-3 shows dimensions of the wiers and culverts.

Location 1 intercepts the extreme western location of expected leakage flow. Locations 1 and 2 together represent all runoff west of that flowing into Location 3. Location 3 (at the culvert) intercepts the most probable drainage path for leakage west of the power tunnel alignment. Location 4 measures most of the drainage from the immediate east side of the power tunnel alignment.

Location 5, the wier at the adit portal, monitors the present flow from leaks in the power tunnel. Location 6 is a 36-inch-diameter culvert at the lowest switchback in the road to Long Lake surge tank adit. It is included to measure all remaining flow (beyond Location 4) on the east side of the power tunnel/penstock.



NOTES: 1. #1, 2, 4, & 5 ARE WIERS
2. #3 & 6 ARE CULVERTS.
3. TAKE READING @ OR NEAR LOW TIDE.

LACHEL & ASSOCIATES
GOLDEN, COLORADO

LOCATION OF WIERS AND CULVERTS — FIGURE D-1

WIER CULVERT FLOW RECORDING

PRECIPITATION *

DATE

WIER OR CULVERT NUMBER

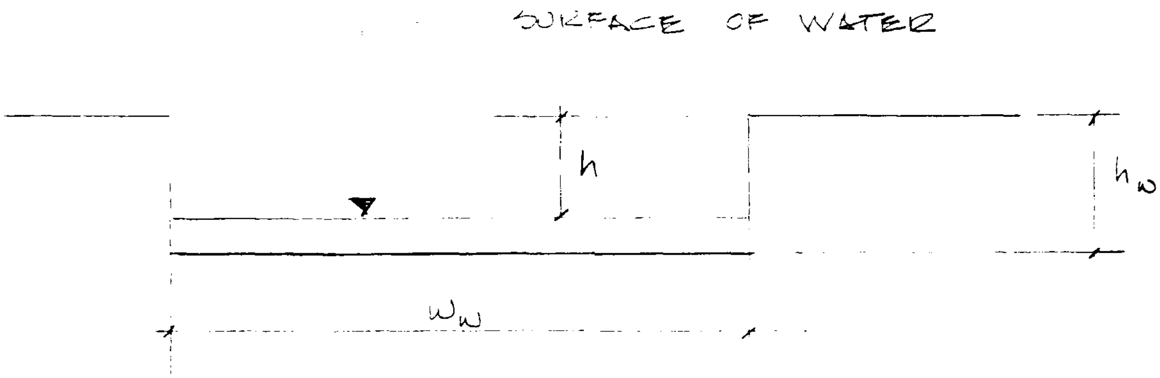
	1	2	3	4	5	6
INITIAL RECORDINGS (Wier dimensions or Culvert Diameter)						
DAILY READING (ft) (See method of measurement sketches)						

LACHEL & ASSOCIATES
GOLDEN, COLORADO

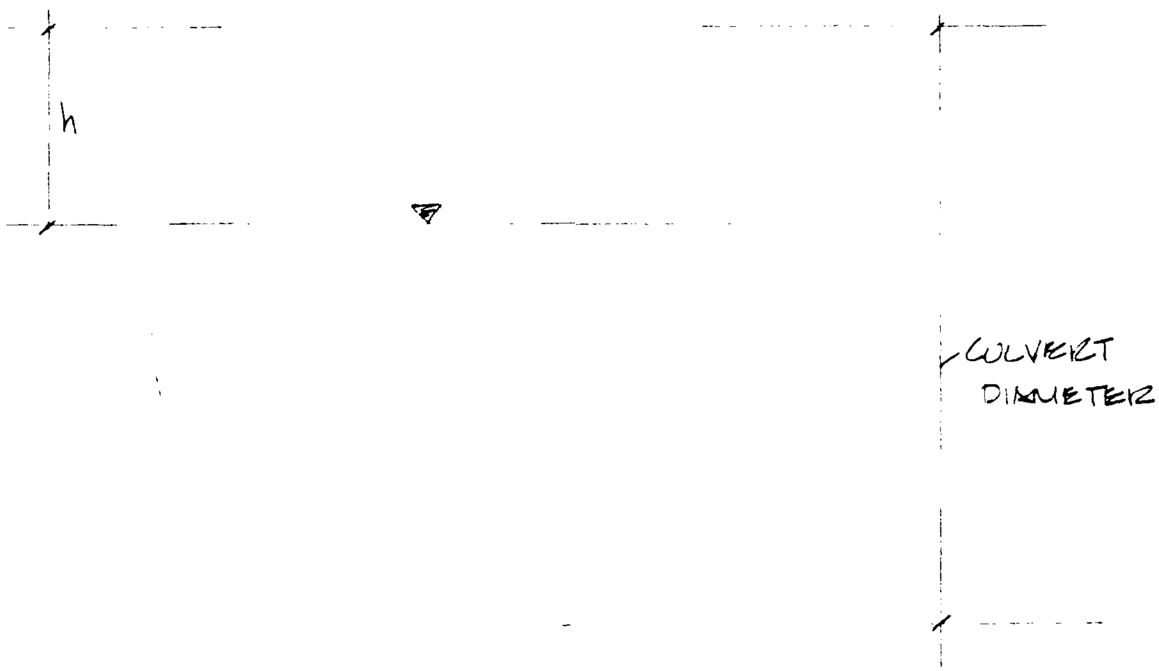
WIER AND CULVERT FLOW RECORDING FORM

FIGURE D-2

* [illegible]



WIER DIMENSIONS



CULVERT DIMENSIONS.

WIER AND CULVERT DIMENSIONS

METHOD OF MEASUREMENT

LACHEL & ASSOCIATES

FIGURE D-3

APPENDIX E

LAKE TAP REPORTS

polarconsult alaska, inc.

ENGINEERS • ARCHITECTS • ENERGY CONSULTANTS

Department of the Army
U.S. Army Corps of Engineers
Anchorage, Pouch 898
Alaska 99506-0898

12th December 1988

Contract DACW 85-85-C-0003 of 18th December 1984

A-E Services, Title I: Lake Tap Design
A-E Services, Title II: Construction Inspection During Lake Tap Construction

Lake Tap Specialist's Short Summary of Events

The Assignment

Polarconsult's lake tap specialist is Finn Kvingan, who in the following is referred to as the Lake Tap Specialist (The LTS). Finn Kvingan assisted C.O.E. on the project for the lake tap in Long Lake, Snettisham, phase I.

Polarconsult's assignment relating to the lake tap under Crater Lake covered by the above contract comprised design and document review of a lake tap design produced by C.O.E., detailed design and description of the tunnel from the gate shaft to the lake tap approximately 222' under the lake level, conceptual design of a trash rack and construction inspection during critical phases of the construction work including the lake tap firing.

Design Review

The design and document review revealed that the plan chosen for the lake tap was located where the lake bottom was very steep, and the bedrock was covered with 20' to 25' of overburden. This great amount of overburden consisting of boulders, logs, roots and fine grained material would present the imminent risk of a landslide, if the lake tap were placed in this location, resulting in the intake quickly being blocked by the overburden material.

C.O.E. had planned to remove this overburden by scraping. The LTS considered that scraping here would be technically very difficult, the operation would be very expensive indeed - C.O.E. estimated a cost of the order of $ 5 million - and a successful outcome would by no means be assured. Furthermore, The LTS considered that the plans were based on an unreliable bathymetric survey.

C.O.E. had planned to execute the lake tap by the wet method.

Polarconsult's Proposals

Following the design and document review, Polarconsult submitted proposals for supplementary survey work and for certain changes, viz.:

- Polarconsult proposed that an experienced Norwegian team of seismic surveyors be brought in to execute a seismic survey from the lake ice with the object of obtaining a reliable basis on which to choose a less risky location for the lake tap.

  The LTS had studied the hillside over the shoreline to picture how glaciers in earlier times had moved and concluded, that the chances of finding a sounder area for the lake tap were very good.

- Polarconsult proposed that the lake tap method be changed from the wet method to the dry method. The implications relating to safety, the function of rocktraps and the maximum pressure on the bulkhead were discussed with C.O.E.

C.O.E. accepted both of the above proposals.

Seismic Survey

On January 4th 1986 The LTS arrived with his seismic team, and the next day all instruments and other equipment were brought up onto Crater Lake. It took 3 days work on the ice to find a sound area for the lake tap.

5 seismic profiles were shot.

The selected lake tap area had the correct depths, no overburden and - as far as could be seen - there appeared to be no danger from landslides in this area.

The condition of the rock was generally good with some fracturing of the top of the bedrock.

Polarconsult presented these seismic profiles with their coordinates to C.O.E.

Revised Design of Lake Tap

Polarconsult proceeded to complete the revised design for the tunnel from the gateshaft to the lake tap including drawings and descriptions for rock traps, drill pattern, probe holes and pilot holes. The completed material for use as tender documents was delivered to C.O.E.

A conceptual design for a trash rack was also produced by Polarconsult.

The construction contract was awarded to Pacific Venture, Inc.

Inspection During Construction Work

January 1988

From January 23rd 1988 to the middle of February The LTS was at the site monitoring the tunnel driving to the plug area. In this period pilot holes and probe holes were drilled and grouting work was done.

A zone of weak rock crossed the area, where the revised design called for rock trap No. 2. The LTS on the spot designed a modified rocktrap No. 2, which was relocated upstream of the weak zone. The weak zone penetration was lined with concrete.

April 1988

On April 4th The LTS returned to Snettisham. At that time the gate shaft was excavated. The drilling of the lake tap plug had been completed. There was plenty of water on the face, but no more grouting was required. 23 of the drill holes had to be fitted with plastic pipes. During The LTS's visit rock trap No. 1 was excavated.

Final Work on Tunnel

Between April 1988 and 15th October 1988 rock traps Nos. 2 and 3 were excavated, and all other tunnelling, service room execavation and gate and service installation work was completed.

October 1988

The LTS returned to Snettisham October 15th 1988 to monitor the firing of the lake tap.

The drill holes in the plug section were controlled, and more plastic pipes had to be put in, because the water leakage had changed since the last visit.

After a few days with controlling all necessary equipment and materials for the last shot, there was a meeting with the tunnel crew.

At this meeting the lake tap procedures, the safety etc. were discussed.

It was desired to start loading the plug at midnight (21-22 October), but before this time crushed ice had been transported up to the gate area, and the ice plug was about 70% finished when loading started.

At the same time the firing cable, pressure cells and instruments were controlled.

It was a cold and wet job for the crew, and it took about 3 hours more than expected to finish all the work from start of loading to firing of the plug. The delay arose because the el-detonators had to be connected in 4 series parallel instead of 2 series which was planned, the reason being that the quality of the detonators was not up to the required standard.

At 15 o'clock all materials, pumps and crew were out of the tunnel. The ice plug was finished and both gates closed.

When the last man from the tunnel crew climbed out of the shaft into the service room, and the last measuring of the resistance for the detonators was done, the instruments for measuring the water pressure started.

3 seconds later the "button was pushed" and the shot went off.

After a short time one could hear a loud noise from the bottom of the shaft when air and water changed places and crushed ice crashed into the bulkheads, as was to be expected.

The highest pressure on the bulkhead arose after 21 seconds and reached approx. 400 feet of waterhead (report from Leif Vinnogg refers).

The lake tap in Crater Lake was fired Friday 22.10.88 at 1515 and everything went as it was planned.

Just after the blast Norwegian Linje-Aquavit was served in the service room. This is a Norwegian tradition when a lake tap is fired.

Comments after the Event

Instead of using snow to build up the snow plug, it was for logistical reasons decided to use crushed ice. A snow plug would have reduced the pressure on the bulkhead by about 15%. Crushed ice does not have this pressure-reducing effect on account of the voids between the pieces of ice.

On the water side of the lake tap plug the rock was known to be quite fractured. The open joints were nearly vertical. The LTS would expect that within 4' of the bedrock face the intake will be irregularly funnelled with a larger diameter at the bedrock face. This will reduce the loss of head but may cause problems for the placing of the trash-rack frame.

We volunteer the following opinions on the work and design seen by our LTS:

- The excavation work in the tunnels and shaft was of good quality.

- The concrete work was everywhere of a high standard.

- The road bed in the access tunnel to the gate shaft was rough and caused transportation problems.

- The LTS was surprized at what he considered the unnecessarily high quality of the gateshaft construction and the very large size of the service room.

Final Inspection of the Drawdown of Crater Lake

Polarconsult suggests that C.O.E. might want to consider a final inspection visit by our LTS to take place on the occasion of the first drawdown of Crater Lake. During this inspection visit, he could inspect the lake tap tunnelling and rock traps after the event in order to provide expert feed-back to C.O.E. on safety aspects, and could assist at the critical insertion of a prefabricated trash rack assembly in the lake tap orifice.

We would conclude by stating that working for C.O.E. on this project has been a pleasure, we have greatly appreciated the cooperation we have received from C.O.E. personnel. Finn Kvingan has only pleasant memories from Elmendorf and Snettisham.

polarconsult

We hope there may be other opportunities to service C.O.E. in future projects, where the experience of Norwegian hard-rock practice could prove of use.

With our best regards
POLARCONSULT ALASKA, INC.

Finn Kvingan,

Finn Kvingan
Lake Tap Specialist

Alaska Contractor's License Number AA0006

Washington Contractor's License Number PACIFV*342OM

RECEIVED DEC 22 1988

PACIFIC VENTURES INC.

General Contractors

December 16, 1988

CTR-SP-982

RESIDENT ENGINEER
Elmendorf Resident Office
P. O. Box 898
Anchorage, Alaska 99506-0898

Reference: Crater Lake Main Contract
Snettisham Project, Alaska
Contract No. DACW85-86-C-0019

Dear Sir,

During the Lake Tap your representatives agreed with the Norconsult representatives that rather than training the Government representatives to obtain the Lake Tap readings, as specified in Section 13C..7, Norconsult would provide copies of the Lake Tap read-outs.

Please find attached Norconsult letters of December 12, 1988, and November 29, 1988, and the Lake Tap Monitoring Report dated October 21, 1988.

Sincerely yours,

PACIFIC VENTURES, INC.

Ralph R. Mason

Ralph R. Mason

RRM:blb
Attachment

cc: Resident Engineer Field Office - Snettisham

Norconsult
Consulting Engineers
Architects
and Economists

Pacific Ventures Inc.
P.O.Box 3407, Bellevue
WASHINGTON 98009
U. S. A.

Sandvika, 12 December 1988
L0010006.LV

Date
Our ref.
Your ref.

Crater Lake, Snettisham Project, Alaska

Dear Ralph,

Concerning the "training of Government personnel in the procedure for obtaining blast readings" I agree that I promised to send you the blast read-outs.

However, as the original graphic recordings consist of a paper of 35 m (113') length, I found it unpractical to copy, so I transferred the pressure-time series to tables and to the graphs shown in the report. As you are interested in the original recordings, I have copied the recordings from the first 80 sec (8 meters of paper) including the calibration signal. The table with the recorded pressure-values are also enclosed.

For your information - when I connected and calibrated the recording instruments at the gate service room, a couple of engineers from the Corps of Engineers were looking at parts of my work. If I remember correctly, their names were Larry Nelson and Tom Eidson.

I hope this is satisfactory, if not, please contact me again.

Sincerey yours

Leif Vinnogg
Leif Vinnogg

Encl. BY MAIL

Consulting Engineers
Architects
and Economists

Pacific Ventures
P.O.Box 3407. Bellevue
WASHINGTON 98004
U S A

RECEIVED
DEC 1 3 1988
PACIFIC VENTURES INC.

Att.: Vincent Volpe

Date 29th November 1988
Our ref. L0009026.LV
Your ref.

Snettisham Project, Alaska
Crater Lake
Lake Tap Monitoring
REPORT

Enclosed please find our report from the measurements at Crater Lake. We hope you find the documentation satisfactory. If you feel you need more information, please contact us.

However, the lake tap was successfull as far as the measurements could tell, and it was a pleasure to cooperate with your colleagues at the site.

Yours truly

NORCONSULT INTERNATIONAL A.S.

Leif Vinnogg

Leif Vinnogg

Enclosures:

3 copies of report

Pacific Ventures Inc.

Snettisham Project, Alaska

CRATER LAKE

Report from

LAKE TAP MONITORING

October 21, 1988

CONTENTS

Plant description

The intake tunnel from the lake tap point to the gate shaft is shown in fig. 1. The intake reservoir, Crate Lake, was at its natural surface elevation 1019' (310,6 m) or slightly above. The lake tap point was planned to be at elevation 820' (250 m) and the gate sill at elevation 789' (240,5 m).

The gate arrangement is shown in fig. 2. A wire operated bulkhead gate with upstream seals is used for revision and the main gate is a slide gate with downstream seals and oilhydraulic hoist. At the top of the shaft at elevation 1040' (317 m) the gate machinery is placed in a rock cavern, "gate service room". The lake tap blasting was done with the bulkhead gate closed and air at atmospheric pressure between the lake tap point and the bulkhead. The air acts as an aircushion being compressed by the floodwave in the first phase after the blasting. The tunnel has three "rocktraps" which are supposed to collect rocks transported by the floodwave, and in addition the "traps" will dissipate a lot of energy from the wave front, i.e. reduce the transient pressure rise at the bulkhead. As a special protection for the bulkhead a plug of iceblocks and crushed ice was built in front of the bulkhead.

Measuring equipment

Four pressure transmitters were installed to monitor the filling process (pressure, time) after the blasting. They are indicated on fig. 1.

- no. 1 on the upstream side of the tunnel lining at elevation 799' (234,8 m), fixed to a rock bolt.

- no. 2 on the rock wall in the lower part of rock trap 3 at elevation 783' (238,7 m), fixed to a rock bolt.

- no. 3 on the upstream side of the concrete plug for the gate, i.e. at the upstream end of the ice plug at elevation 797' (242,9 m), fixed to the end of the 2" steel pipe for the signalcables through the concrete.

- no. 4 on the bulkhead front plate (1/2" pipe threads in the plate) at elevation 793' (241,7 m).

The signal cable from transmitter no. 1 was led through a 2" plastic pipe through the concrete lining and further fixed with concrete nails and plastic strips to the concrete banquette covering the permanent piezometer pipes. From transmitter no. 2 the cable was fixed in the same way. At corners and sharp edges the cables were protected with a quick-hardening concrete. Through the concrete plug for the bulkhead the cables were led through a 2" steel pipe that was sealed with groating material. The cable from the transmitter no. 4 was on the downstream side of the bulkhead. All four cables were fixed together on the safety cage of the ladder up to the gate service room where the recording instruments were placed.

Specifications of measuring equipment:

- Pressure transmitters, type Wika (West Germany), mod. 891.14.520,
  principle: piezoresistive
  range: 0 - 17 bar (0 - 535' water head)
  output signal: 4 - 20 mA
  input voltage: 24VDC
  linearity error: <0,5% FS
  calibration sheet fig. 3
  The submerged transmitters were sealed with silicon grease,
  vulcanising tape and a cover of ordinary plastic tape.

- Cables, twisted pair, 2 x 0,52 mm^2 (20 AWG) tinCu, shilded and with PVC jacket.

- Pen oscillographic recorder with preamplifiers, type Graphtec (Japan), "Linearcorder" Mark VII NR 3101, thermal writing

6 channels (4 used)
recording amplitude 40 mm
maximum paper velocity 500 mm/sec
power supply 110V AC

- Tape recorder Racal (UK) "Store 7 DS"
  7 channels (4 used)
  7 different tape velocities

The measuring circuit, for each of the 4 pressure transmitters is shown on Fig. 4.

Measuring results

The recorders were started just before the blasting, the paper speed of the pen recorder was 100 mm/sec.

The air pressure wave from the explosion was registered as a short pressure pulse on the transmitters no. 1, 2 and 3. From the time delay between the pulse on each transmitter and the known distance a velocity of 1000 - 1200 feet/sec could be calculated. The recording showed that the pressure rose to about 30% above atmospheric and this lasted for about 0,1 sec before the pressure fell again.

Then the water started to fill the tunnel and the pressure increased. After 5,5 sec. transmitter no. 1 was lost and at 18 sec transmitter no. 2 was lost. However, no. 3 and 4 were recorded correctly. The pressure peak was reached after 21 sec. and the peak was about 80% above the static reservoir level related to the gate level. Then 4 - 5 damped oscillations were recorded with decreasing amplitude and period (18 to 10 sec.) The decreasing periode was caused by the change in elastisity of the water-air mixture in the tunnel as air escapes back into the reservoir.

The pressure recordings are drawn on a suitable timescale shown in fig. 5 and 6.

Transmitter No. 1 shows a faster pressure rise than the others because the entrance to the concrete lining in the tunnel represents a considerable restriction for the flow.

Transmitter No. 2 shows a pressure-time graph very similar to No. 3 and 4, but it is partly damaged and the remaining signal has an offset compared with the stabilised water pressure from Crate Lake.

Transmitter No. 3 and 4 shows that the pressure near the gate rises to a maximum level near elevation 1200 feet (365,8 m). Related to the gate sill at elevation 789 feet (240,5 m) and a pool surface level of 1019 feet (310,6 m) the relative pressure rise is

$$\frac{h}{h_o} = \frac{1200 - 789}{1019 - 789} = \underline{1,79}$$

The actual recordings with time scale 100 mm/sec show no sharp pressure peaks.

Accuracy of the measurements

The pressure transmitters were calibrated in our laboratory with a dead weight manometer and a digital precision amperemeter, and the maximum deviation from nominal value was 0,25% FS, see fig. 3.

Looking at the recording of the stabilised water pressure (Crater Lake level) the following table gives a comparison between measured and calculated pressures.

Transmitter no.	Transmitter elevation	Transmitter depth below surface (feet)	Measured pressure (bar)	(feet)	(m)	Derivation
2	783'	236'	7.55	252,6'	(76,98)	16,6'
3	797'	222'	6,68	223,5'	(68,11)	1,5'
4	793'	226'	6,82	228,1'	(69,52)	2'

The converting of the pressure measurements from bar to feet water head is shown:

1 foot = 0,3048 m

1 bar = 10,197 m water head at standard gravity,

g_o = 9,807 m/sec^2 and water density 1000 kg/m^3

Local gravity g_1 = 9,818 at 58,5^o latitude.

Density of water 1000,2 kg/m^3 at 5^o C and 4 bar.

Density of air 1,2 kg/m^3 (atmosphere)

Thus the equivalent local water head is

$$1 \text{ bar} = 10,197 \; \frac{9,807}{9,818} \; \frac{1000}{(1000,2-1,2)} = 10,196 \text{ m water head} = \underline{\underline{33,451'}}$$

The original graphic recording has a scale of 2,2 mm/bar and it could be read with an accuracy of ± 0,1 mm which correspond to ± 0,045 bar or ± <u>1,52'</u> (± 0,46 m).

The tolerances for the transmitters (± 0,25% FS) ± 1,34' (± 0,41 m) and for the electronic part of the graphich recorder (± 1% FS) ± 3,04' (± 0,93 m) must also be accounted for.

The maximum error is the sum

$$f_{max} = 1,52 + 1,34 + 3,04 = \underline{\pm 5,9' \; (\pm 1,8 \text{ m})}$$

Probably the error will be within

$$f_p = 1,52^2 + 1,34^2 + 3,04^2 = \underline{\underline{\pm 3,65'}} \; (\pm 1,11 \text{ m})$$

Thus the transmitter no. 3 (ice front) and no. 4 (gate) obviously have been recorded with good accuracy, but no. 2 (3rd rock trap) shows an error larger than expected. This error is most probably caused by the partial damage of the transmitter/cable indicated by the lost signal between 18 sec. and 65 sec.

The lake tap, comments

From the recorded signals the lake tap must be considered as successful. The inflow of water gave a smooth pressure rise graph without any sign of irregularities. The filling time was as expected which means that the blasted hole had the correct size.

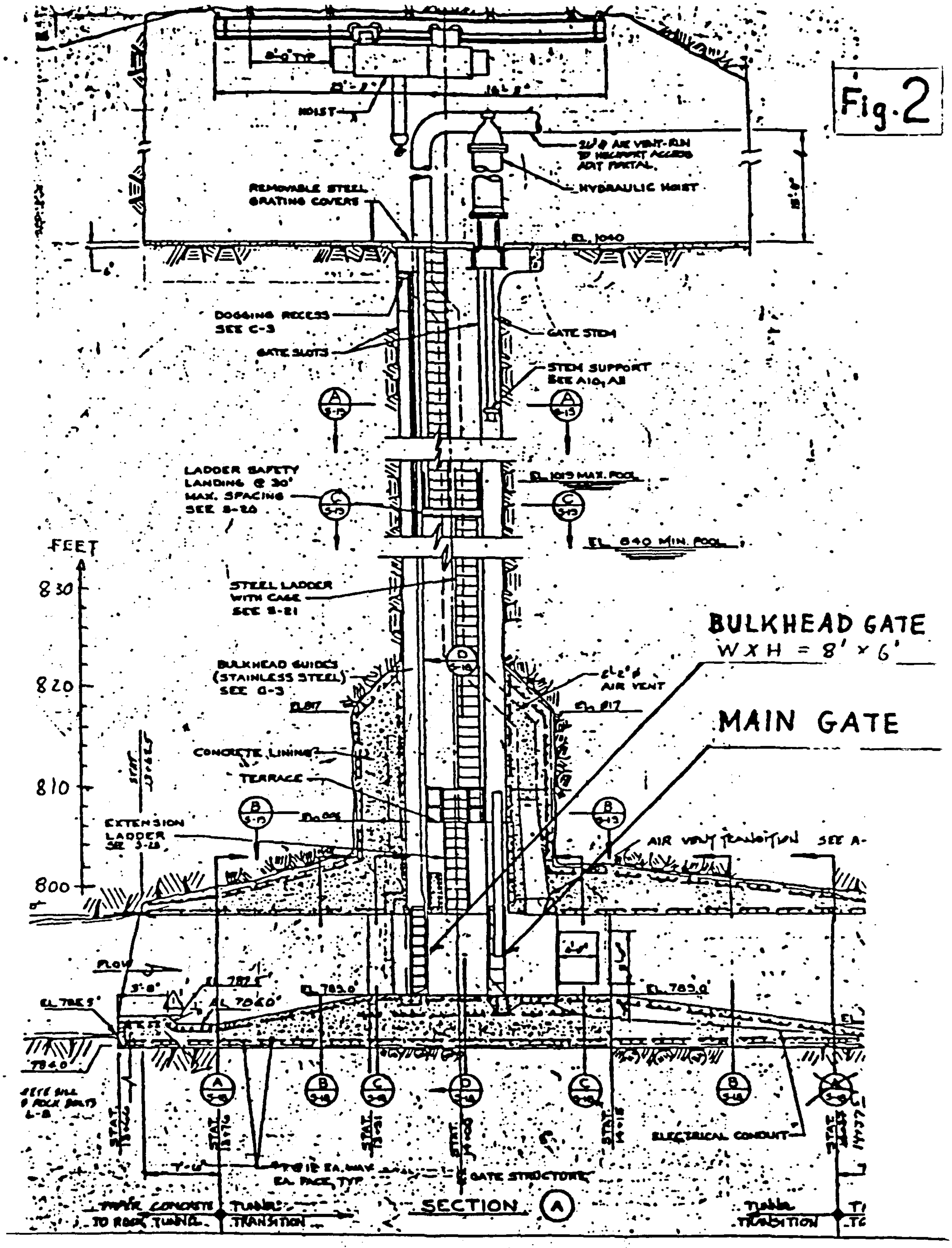
The maximum pressure rise at the bulkhead gate was 80% above the normal static pressure on the gate, which normally is acceptable. There were no sharp pressure peaks recorded on the front plate of the bulkhead, thus it has not been exposed to any blows from transported rock or wave shocks. The purpose of the ice plug was to prevent this.

Sandvika, 14 November 1988

Leif Vinnogg

Leif Vinnogg

Fig. 2



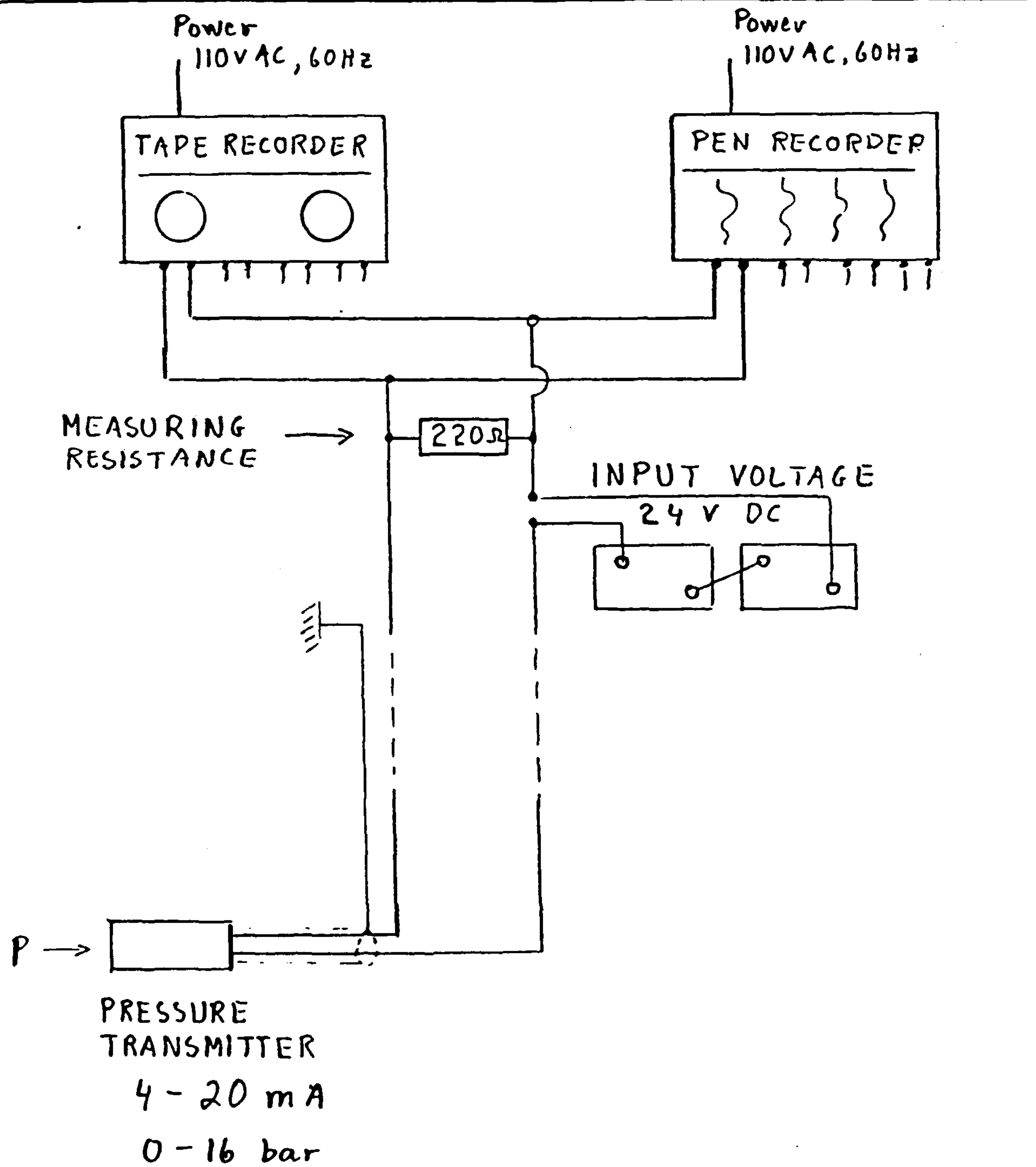
CRATER LAKE

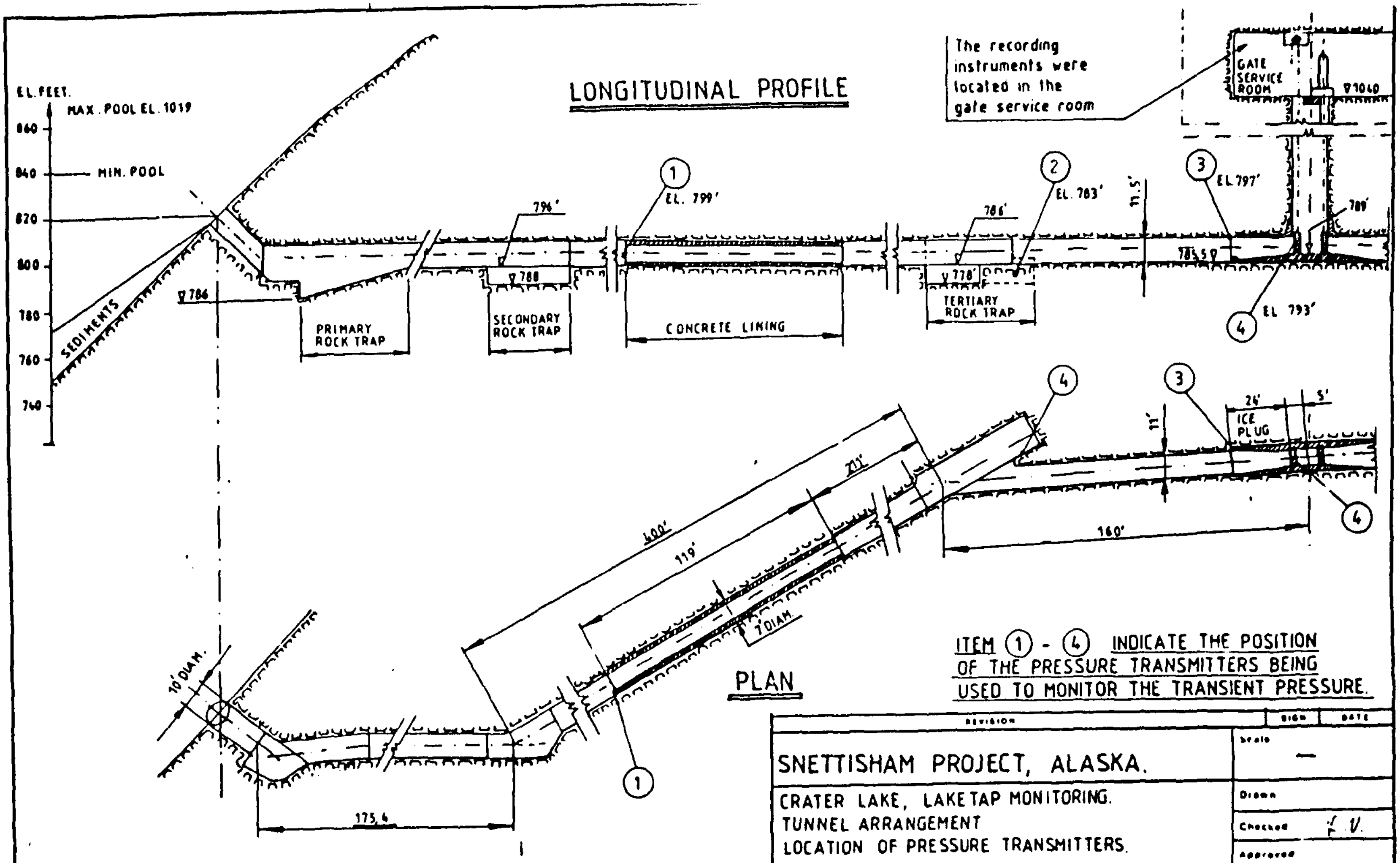
Intake gate Arrangement

Oppdragsgiver: PACIFIC VENTURE Inc.	O.nr.:	Arkiv nr.:	Side: Fig. 3
Oppdrag: Snettisham project, Alasca	Dato:	Sign.:	
Sak: Crater Lake, Lake tap			
Pressure transmitter. Calibration			

REFERENCE		TRANSMITTER NO.			
Pressure	Current	1	2	3	4
(bar)	(mA)	(mA)	(mA)	(mA)	(mA)
1	5	5,01	5,00	5,01	5,00
2	6	6,00			
3	7	7,00			
4	8	7,99	7,98	7,99	7,97
5	9	8,99			
6	10	9,99			
7	11	10,99			
8	12	11,99	11,97	11,98	11,96
9	13	12,99			
10	14	-			
11	15	14,98			
12	16	15,98	15,98	15,98	15,96
13	17	16,98			
14	18	17,98			
15	19	18,98			
16	20	19,97	19,98	19,97	19,96
„Budenberg" 380 L Dead weight manometer		„Lutron" DM - 6016 Digital multimeter,			

Oppdragsgiver: PACIFIC VENTURE Inc.	O.nr.:	Arkiv nr.:		Side: Fig. 4
Oppdrag: Snettisham project, Alaska	Dato:	Sign.:	ℓ.V.	
Sak: Crater lake, lake tap				
Pressure measuring circuit				





SNETTISHAM PROJECT, ALASKA.

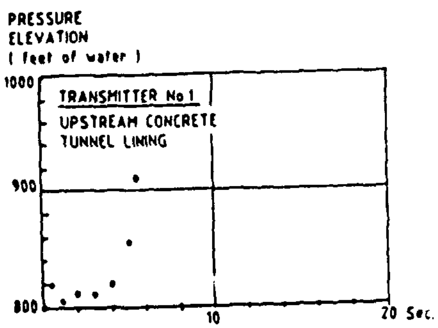
CRATER LAKE, LAKETAP MONITORING.
TUNNEL ARRANGEMENT
LOCATION OF PRESSURE TRANSMITTERS.

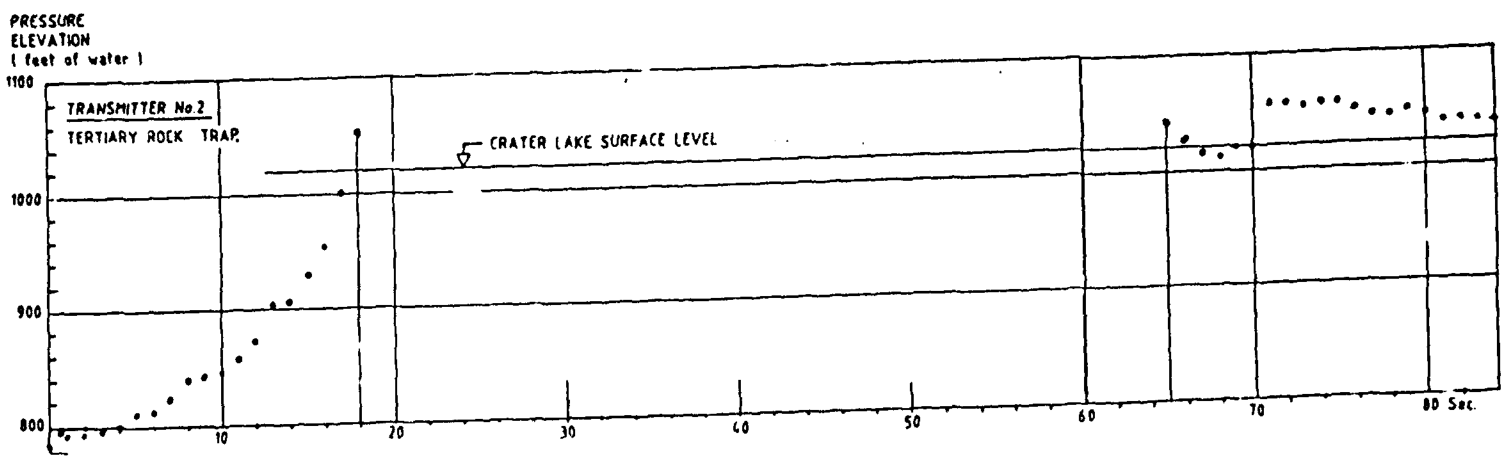
Scale	—
Drawn	
Checked	
Approved	
Supersedes	
Job	

NORCONSULT A.S.

Fig. 1

CRATER LAKE , LAKE TAP	Fig. 1
Pressure recording No. 1 and 2	

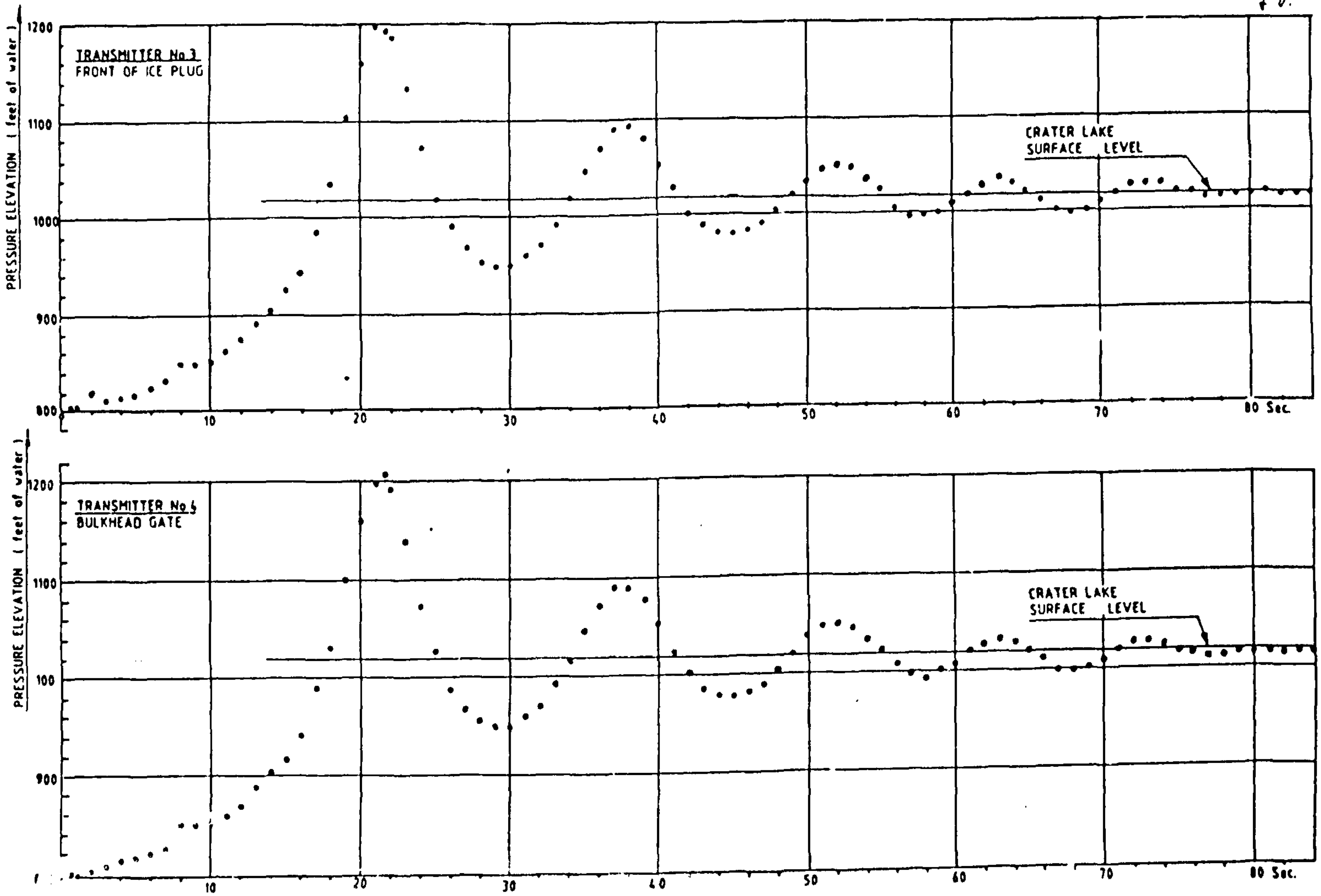




CRATER LAKE, LAKE TAP

Pressure recording No. 3 and 4

Fig. 6



APPENDIX F

GEOLOGIC CORE LOGS

SUMMARY OF EXPLORATIONS

HOLE NO.	LOCATION N	LOCATION E	START DATE	Finish DATE	SIZE CORE	ANGLE DRILLED FROM VERT.	DEPTH	REMARKS
DH-98	93614	86377	09-30-72	10-08-72	NX	0°	219.2'	Rock Trap
DH-99	95473	91607	09-27-72	10-09-72	NX	0°	350'	Power Tunnel
DH-100	93611	86371	10-11-72	10-19-72	NX	35°	310'	Lake Tap and Rock Trap
DH-101	94116	88088	10-13-72	10-19-72	NX	0°	232'	Power Tunnel
DH-102	93616	86380	10-21-72	10-27-72	NX	45°	334'	Crossed Hilltop Fault
DH-103	94271	88228	10-30-73	10-07-73	NX	0°	366.8'	Power Tunnel
DH-104	95454	91480	09-17-73	10-05-73	NX	0°	454.4'	Power Tunnel
DH-105	94135	88085	09-21-73	10-07-73	NX	37.5°	325.9'	Power Tunnel
DH-106	95159	91259	10-15-73	10-26-73	NX	35°	415.8'	Power Tunnel
DH-107	94886	90405	11-12-73	11-22-73	NX	37°	340.2'	Power Tunnel
DH-108	93451	86209	10-04-74	10-10-74	NX	0°	259.3'	Lake Tap
DH-109	93685	86244	10-12-74	10-19-74	NX	0°	277.7'	Lake Tap
DH-110	93549	86220	10-20-74	10-25-74	NX	0°	271.1'	Lake Tap
DH-111	93729.8	86720.3	07-29-82	08-21-82	NQ	0°	747.3'	Gate Chamber
DH-112	93767.6	86703.6	09-10-82	10-02-82	NQ	30°	602.1'	Gate Chamber
DH-113	93731.0	86699.5	10-06-82	10-14-82	NQ	30°	392.2'	Gate Chamber
DH-114	93731.0	86934.0	10-06-82	10-17-82	NQ	30°	592.1'	Power Tunnel
DH-115	95300.4	91992.3	09-09-82	09-28-82	NQ	45°	650.1'	Penstock

DH-116	93645	86124	07-18-84	07-20-84	NQ	0°	26.8'	Lake Bottom
DH-116A	93641	86144	07-20-84	07-23-84	NQ	0°	51.0'	Lake Bottom
DH-117	93656	86120	07-27-84	08-09-84	NQ	0°	98.2'	Lake Bottom
DH-118	93646	86111	08-21-84	08-23-84	NQ	0°	57.2'	Lake Bottom
DH-119	93655	86168	08-31-84	09-02-84	NQ	0°	20.6'	Lake Bottom
DH-120	93684	86201	09-03-84	09-04-84	NQ	0°	8.2'	Lake Bottom
DH-121	93723	86201	09-05-84	09-06-84	NQ	0°	19.6'	Lake Bottom
DH-122	93632	86218	09-07-84	09-07-84	NQ	0°	17.1'	Lake Bottom
DH-123	93702	86279	09-08-84	09-08-84	NQ	0°	9.7'	Lake Bottom
DH-124	93666	86198	09-14-84	09-14-84	NQ	0°	18.8'	Lake Bottom
DH-125	93445	86137	09-16-84	09-20-84	NQ	0°	58.7'	Lake Bottom
DH-126	93441	86161	09-23-84	09-27-84	NQ	0°	77.9'	Lake Bottom
DH-127	93441	86190	09-29-84	09-29-84	NQ	0°	23.5'	Lake Bottom
DH-128	93439	86241	09-30-84	10-03-84	NQ	0°	17.8'	Lake Bottom
DH-128A	93445	86243	10-09-84	10-10-84	NQ	0°	43.8'	Lake Bottom
DH-129	93405	86252	10-04-84	10-06-84	NQ	0°	18.8'	Lake Bottom
DH-129A	93405	86252	10-06-84	10-06-84	NQ	0°	35.7'	Lake Bottom
DH-130	93441	86279	10-07-84	10-07-84	NQ	0°	27.3'	Lake Bottom
DH-131	93406	86155	10-11-84	10-13-84	NQ	0°	29.7'	Lake Bottom
DH-132	93465	86142	10-14-84	10-16-84	NQ	0°	40.0'	Lake Bottom
DH-133	92845	86364	10-21-84	10-30-84	NQ	0°	201.3'	Crater Lake
DH-134	92848	86356	11-05-84	11-08-84	NQ	0°	133.5'	Crater Lake

SUMMARY LOG — HOLE NO. DH 98

SUMMARY LOG HOLE NO. DH 98	N 93,614 / E 86,377	SHEET 1 OF 3 / SURFACE ELEV. 1024.7
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 30 Sept 72	COMP. 8 Oct 72
DEPTH OF HOLE 220 ft.	DEPTH OF OVERBURDEN 0.85 ft.	DIAM. OF HOLE Nx Core
ROCK DRILLED 219.15 ft.	CORE RECOVERED 100%	% RECOVERY 100%
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	Clayton Rasmussen

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1024.7	0.0		Surface		
[illegible]	0.9		Overburder - boulders; Top of Rock		
			Quartz Diorite, black and white hard and fresh with Gneissic banding and minor jointing		Core lengths 0.1 to 2.0 ft.
	10				
	20				20'-30'; pressure test water flowing to DH-102
992.7	30		33.9 core showed minor high angle jointing. Core below 33.9 ft. showed no natural joints		Lost circulation 32 to 33 ft. Backflow 33 to 35 ft.
	40				Core lengths 0.2 to 5.0 ft.
	50		Quartz Diorite		
	60				
	70				Core lengths 1.0 to 5.0 ft.
	80				
	90		Quartz Diorite		Core lengths 2.0 to 5.0
924.7	100				

NPA Form 7(Test)

PROJECT [illegible] | HOLE NO. DH 98

SUMMARY LOG — HOLE NO. DH 98 cont'd

SUMMARY LOG HOLE NO. DH 98 cont'd	N 93614 / E 86377	SHEET 2 OF 3 / SURFACE ELEV. 1024.7
PROJECT	DRILL DATES: START 30 SEPT 72	COMP. 8 OCT72
DEPTH OF HOLE 220.0 FT.	DEPTH OF OVERBURDEN 0.85 FT.	DIAM. OF HOLE NX CORE
ROCK DRILLED 219.15 FT.	CORE RECOVERED 219.15 FT.	% RECOVERY 100
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	CLAYTON RASMUSSON

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
924.7	100		Quartz Diorite- as above		Core lengths 2.0 to 5.0 ft.
	100				
	120				Core lengths 0.3 to 3.5 ft.
	130				Core lengths 0.5 to 5.0 ft.
	140		Quartz Diorite		
	150				
	160				
	170				
	180				Core lengths 0.5 to 2.0 ft.
	190		Quartz Diorite		
424.7	200				

NPA Form 7(Test)

PROJECT Snettisham (Crater Lake) | HOLE NO. [illegible]

SUMMARY LOG
HOLE NO. DH 99 cont'd

N	93614
E	86377
SHEET	3 OF 3
SURFACE ELEV	1024.7
PROJECT	Snettisham (Crater Lake)
DRILL DATES: START	30 SEPT 72
COMP.	8 OCT 72
DEPTH OF HOLE	220.0 FT
DEPTH OF OVERBURDEN	0.85 FT
DIAM OF HOLE	NX CORE
ROCK DRILLED	219.85 FT
CORE RECOVERED	219.15 FT.
% RECOVERY	100
ANGLE FROM VERT	
AZIMUTH FROM NORTH	
COMPILED BY, DATE	CLAYTON RASMUSSON
DISTANCES: VERTICAL, ; HORIZONTAL,	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
824.7	200		Quartz Diorite- as above		Core lengths 0.5 to 2.0 ft.
	210				Core lengths 0.1 to 2.0 ft
804.7	222				
			Bottom of Hole		

DEPTH 220.0 FT.
OVERBURDEN 0.85 FT.
ROCK DRILLED 219.15
CORE RECOVERED 219.1 FT
CORE RECOVERED 100
ELEV. OF BOTTOM 804.7

Pressure Test Results

From	To	K(X10^{-5})
20'	30'	333.9
30'	40'	1290.8
40'	50'	138.1
50'	220'	0.0

NPA Form 7(Test) APR 66 — **PROJECT** Snettisham (Crater Lake) — **HOLE NO.** DH 99

SUMMARY LOG
HOLE NO. Dh 99

N	95,473
E	91,607
SHEET	1 OF 4
SURFACE ELEV	1063.3
PROJECT	Snettisham (Crater Lake)
DRILL DATES: START	27 SEP 72
COMP.	9 OCT 72
DEPTH OF HOLE	350.0 FT
DEPTH OF OVERBURDEN	4.0 FT.
DIAM. OF HOLE	NX CORE
ROCK DRILLED	346.0 FT
CORE RECOVERED	346.0
% RECOVERY	100
ANGLE FROM VERT.	0°
AZIMUTH FROM NORTH	
COMPILED BY, DATE	Clayton Rasmussen
DISTANCES: VERTICAL, ; HORIZONTAL,	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1063.3	00		Surface		
			Overburden, organic and boulders		
1059.3	4.0		Top of Rock		
	10		Quartz Diorite, black and White, hard and fresh with Gneissic banding and minor jointing		Core lengths 0.1 to 1.0 ft.
	20				Core lengths 0.1 to 5.0 ft
	30				
1025			38 to 40 ft. high angle joint		
1023					
	40		44 to 49 ft high angle joint		Core lengths 0.1 to 1.0 ft
			Quartz Diorite		
1019					Core lengths 0.1 to 1.0 ft
1014	50				
	60				Core lengths 0.3 to 0.5 ft
			68 to 71 ft. high angle joint		
	70				Core lengths 0.3 to 0.5 ft.
995					
992					
	80		Quartz Diorite		
	90				Core lengths 0.1 to 4.0 ft
963.3	100				

NPA Form 7(Test) APR. 66 — **PROJECT** Snettisham (Crater Lake) — **HOLE NO.** DH 99

SUMMARY LOG

HOLE NO. DH 99	N 95473 / E 91607	SHEET 2 OF 4 / SURFACE ELEV 1063.3
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 27 SEP 72 COMP. 9 OCT 72	
DEPTH OF HOLE 350.0 FT.	DEPTH OF OVERBURDEN 4.0 FT	DIAM. OF HOLE NX CORE
ROCK DRILLED 346.0 FT	CORE RECOVERED 346.0	% RECOVERY 100
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	CLAYTON RASMUSSON

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
963.3	100		Quartz Diorite - as above		Core lengths 0.1 to 4.0 ft.
	110				
950			113 to 119 ft. 2 high angle joints		Core lengths 0.1 to 0.5 ft.
943	120				
	130				Core lengths 0.3 to 2.0 ft.
927			136 to 136.5 ft. high angle joint		
	140		Quartz Diorite		Core lengths 0.05 to 1.2 ft.
	150				
907 / 906			156 to 157 ft. high angle joint		
	160				Core lengths 0.2 to 2.0 ft
892	170		171 to 172 ft. high angle joint		
	180				
			Quartz Diorite		
	190				
863.3	200				

NPA Form 7(Test) APR. 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 99

SUMMARY LOG

HOLE NO. DH 99	N 95473 / E 91607	SHEET 3 OF 4 / SURFACE ELEV 1063.3
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 27 SEP 72 COMP. 9 OCT 72	
DEPTH OF HOLE 350.0 FT	DEPTH OF OVERBURDEN 4.0 FT.	DIAM. OF HOLE NX CORE
ROCK DRILLED 346.0 FT.	CORE RECOVERED 346.0	% RECOVERY 100
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	CLAYTON RASMUSSON

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
863.3	200		Quartz Diorite - as above		Core lengths 0.2 to 2.0 ft.
	210				
	220				Core lengths 0.5 to 3.5 ft.
	230				Core lengths 0.1 to .25 ft.
	240		Quartz Diorite		
	250				
799.8	260		263.5 ft. high angle joint		
	270				
787.?			275.3 to 276.5 ft. high angle joint		
	280				
	290		Quartz Diorite		Core lengths 0.1 to 0.3 ft.
763.3	300				

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 99

SUMMARY LOG — HOLE NO. DH 99

N 9521 (?)	E 91607	SHEET 4 OF 4 — SURFACE ELEV 1063.1
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 27 SEPT 72	COMP. 9 OCT 72
DEPTH OF HOLE 350.0 FT	DEPTH OF OVERBURDEN 4.0 FT	DIAM. OF HOLE NX CORE
ROCK DRILLED 346.0 FT	CORE RECOVERED 346.0	% RECOVERY 100
ANGLE FROM VERT	AZIMUTH FROM NORTH	COMPILED BY, DATE — CLAYTON RASMUSSEN
DISTANCES: VERTICAL,	HORIZONTAL,	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
763 (?)			Quartz Diorite - as above		Core lengths 0.1 to 0.8 ft.
	310				
			316 to 318 ft. high angle joint		
			318 to 321.5 ft. high angle crossed joints		
			323 to 324 ft. high angle joint		
738 (?)			325 to 326 crushed zone		Lost 30 circulation
	330				Core lengths 0.1 to 0.8 ft.
			Quartz Diorite		
	350 (?)		BOTTOM OF HOLE		

DEPTH OF HOLE 350.0 FT
OVERBURDEN DRILLED 4.0 FT
ROCK CORED 346.0 FT
RECOVERED 99%
ELEV. AT BOTTOM 713.1 (?)

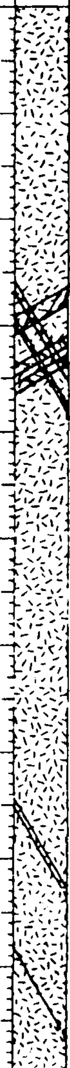
Pressure Test Results

From	To	K (x10⁻³)
40'	50'	25.9
50'	60'	0.0
60'	70'	69.1
70'	110'	0.0
110'	120'	6.9
120'	310'	0.0
310'	320'	0.9
320'	330'	46.6
330'	348'	0.0

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 99

SUMMARY LOG — HOLE NO. DH 100

N 93611	E 86371	SHEET 1 OF 4 — SURFACE ELEV 1019.6
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 11 OCT 72	COMP. 19 OCT 72
DEPTH OF HOLE 310.0 FT	DEPTH OF OVERBURDEN 0.0	DIAM. OF HOLE Nx Core
ROCK DRILLED 310.0 FT	CORE RECOVERED 310.0 FT	% RECOVERY 100
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 251°	COMPILED BY, DATE — Clayton Rasmussen
DISTANCES: VERTICAL, 254.0	HORIZONTAL, 177.6	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1019.6	00		Top of Rock. Quartz Diorite, black and white, hard and fresh with Gneissic banding and minor jointing		Core lengths 0.2 to 3.0 ft.
	10				
			18 to 29 ft. core breaks every 0.3 to 0.5 ft.		Core lengths 0.1 to 2.0 ft.
	20				Core lengths 0.05 to 0.5 ft. Some circulation loss 23 to 28 ft.
			26 to 26.5 ft. closely broken low and high angle fracturing 29 to 30 ft. closely broken		
	30		34 to 36.5 ft. closely broken (low angle fracturing)		Core lengths 0.05 to 0.3 ft.
	40				Core lengths 0.5 to 2.5 ft.
					23 to 60 ft. air bubbles in lake 20± ft. off-shore
	50		Quartz Diorite		Core lengths 1.0 to 4.0 ft
	60				
	70		74.7 ft. high angle joint 75.0 ft. high angle joint		Core lengths 0.5 to 3.0 ft
	80		88 to 89 ft. high angle joint		
	90		Quartz Diorite		
927.2 (?)	100				

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 100

SUMMARY LOG — HOLE NO. DH 100 — SHEET 2 OF 4

N 93611	E 86371	SURFACE ELEV 1019.6
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 11 OCT 72	COMP. 19 OCT 72
DEPTH OF HOLE 310.0 FT	DEPTH OF OVERBURDEN 0.0	DIAM. OF HOLE NX CORE
ROCK DRILLED 310.0 FT	CORE RECOVERED 310.0 FT	% RECOVERY 100
ANGLE FROM VERT 35°	AZIMUTH FROM NORTH 251°	COMPILED BY, DATE CLAYTON RASMUSSEN
DISTANCES: VERTICAL, 254.0 FT	HORIZONTAL, 177.6 FT	

DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
100	Quartz Diorite - as above		Core lengths 0.3 to 5.0 ft.
110			
120			
130			
140	142 to 145.5 ft. high angle joint some breakage		Core lengths 0.4 to 1.5 ft.
	Quartz Diorite gneiss		Core lengths 0.5 to 2.3 ft.
150	155 to 156 ft. crossed high angle joints with chlorite coatings		
160	162 ft. high angle joint		
170	177 to 186 ft. high angle joints breakage		Core lengths 0.5 to 1.5 ft.
180			
190			Core lengths 0.5 to 2.5 ft.
355.1 200	Quartz Diorite		

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 100

SUMMARY LOG — HOLE NO. DH 100 — SHEET 3 OF 4

N 93611	E 86371	SURFACE ELEV 1019.6
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 11 OCT 72	COMP. 19 OCT 72
DEPTH OF HOLE 310.0 FT	DEPTH OF OVERBURDEN 0.0 FT	DIAM. OF HOLE NX CORE
ROCK DRILLED 310.0 FT	CORE RECOVERED 310.0 FT	% RECOVERY 100
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 251°	COMPILED BY, DATE CLAYTON RASMUSSEN
DISTANCES: VERTICAL, 254.0	HORIZONTAL, 177.6	

DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
200	Quartz Diorite - as above		Core lengths 0.5 to 2.5 ft.
			Core lengths 0.3 to 2.5 ft.
210			
220	220 ft. high angle joint		Core lengths 0.3 to 4.5 ft.
230	fracture, sericite coatings		
240	240 to 241.5 crossed high angle fractures No fractures or joints from 241.5 to 310.0 ft.		Core lengths 0.5 to 5.0 ft.
250	Quartz Diorite		
260			
270			Core lengths 1.0 to 5.0 ft.
280			
290	Quartz Diorite, black & white, gneissic texture		
773.3 310			

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 100

SUMMARY LOG

HOLE NO. DH 100	N 93611	SHEET 4 OF 4
	E 86371	SURFACE ELEV 1019.6

PROJECT Snettisham (Crater Lake)	DRILL DATES: START 11 OCT 72	COMP. 19 OCT 72
DEPTH OF HOLE 310.0 FT	DEPTH OF OVERBURDEN 0.0	DIAM OF HOLE NX CORE
ROCK DRILLED 310.0 FT	CORE RECOVERED 310.0 FT	% RECOVERY 100
ANGLE FROM VERT 35°	AZIMUTH FROM NORTH 251°	COMPILED BY, DATE
DISTANCES VERTICAL, 254.0 FT, HORIZONTAL, 177.8 FT		CLAYTON RASMUSSEN

ELEV 1019.6	DEPTH 310	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
			Quartz Diorite - as above		Core lengths 10. to 5.0 ft.
765.7	310		BOTTOM OF HOLE		
			DEPTH 310.0 FT		
			OVERBURDEN 0 FT		
			ROCK DRILLED 310.0 FT		
			CORE RECOVERED 310.0 FT		
			CORE RECOVERED 100%		
			ELEV OF BOTTOM [illegible] FT		

Pressure Test Results

From	To	K x10⁻⁵
[illegible]	40'	[illegible]
[illegible]	50'	[illegible]
[illegible]	80'	[illegible]
30'	40'	[illegible]
90'	140'	[illegible]
140'	150'	[illegible]
150'	160'	10.6
[illegible]	30?'	[illegible]

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 100

SUMMARY LOG

HOLE NO. DH 101	N 94,116	SHEET 1 OF 3
	E 92,989	SURFACE ELEV 1015.4

PROJECT Snettisham (Crater Lake)	DRILL DATES: START 13 Oct 72	COMP. 19 Oct 72
DEPTH OF HOLE 232.0 ft	DEPTH OF OVERBURDEN 4.5 ft	DIAM OF HOLE Nx Core
ROCK DRILLED 227.5 ft	CORE RECOVERED 227.1 FT	% RECOVERY 99.8
ANGLE FROM VERT 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES VERTICAL,	HORIZONTAL,	Clayton Rasmussen

ELEV 1015	DEPTH 00	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
			Surface		
			Overburden, organic and boulders		
1010.9	4.5		Top of Rock		casing set to 5.0 feet
			Quartz Diorite, black and white, hard and fresh (locally altered) with Gneissic banding and minor jointing		Core lengths 0.1 to 3.0 ft
	10				
	20				Core lengths 0.3 to 1.0 ft
	30				
	40				
	50		Quartz Diorite		
	60				Core lengths 0.2 to 2.2 ft
					Core lengths 0.5 to 1.0 ft
	70		High angle joints chemically highly altered		
	80		2 high angle joints low angle joint low angle joint		Core lengths 0.1 to 0.7 ft
	90		Chemically highly altered fragile core iron stained		
915.4	100		Pink/Green Granodiorite		

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 101

SUMMARY LOG

HOLE NO. DH 101 cont'd | **N** 94116 | **E** 88088 | **SHEET** 2 **OF** 3 | **SURFACE ELEV.** 1015.4

PROJECT Snettisham (Crater Lake) | **DRILL DATES: START** 13 OCT 72 **COMP.** 19 OCT 72

DEPTH OF HOLE 232.0 FT | **DEPTH OF OVERBURDEN** 4.5 FT | **DIAM. OF HOLE** NX CORE

ROCK DRILLED 227.5 FT | **CORE RECOVERED** 227.1 FT | **% RECOVERY** 99.8

ANGLE FROM VERT. | **AZIMUTH FROM NORTH** | **COMPILED BY, DATE** CLAYTON RASMUSSEN

DISTANCES: VERTICAL, ; HORIZONTAL,

ELEV. 915.4	DEPTH 100	DESCRIPTION OF MATERIALS	% CORE	REMARKS
		Pink and green Granodiorite chemically altered locally soft and weak		Core lengths 0.1 to 0.7 ft.
	110	110.5 ft high angle joint		Core lengths 0.2 to 2.0 ft.
901		113.5 ft. 45° joint		
897		Quartz Diorite, gneissic		
	120	Pinkish fine grained Granodiorite, gneissic 123 ft. low angle fracture 126 ft. high angle fracture		
	130	130.5 ft. joint 133 to 135 ft. low angle joint, iron stained		Core lengths 0.5 to 2.0 ft.
	140	145 ft. high angle fracture 149 ft. high angle fracture		
866.4	150	Quartz Diorite, gneissic		
86?		Pink and green Granodiorite		
	160	Chemically altered		Core lengths 0.05 to 0.5 ft
848				Core lengths 0.2 to 1.0 ft.
847	170	Quartz Diorite, gneissic		Core lengths 0.02 to 0.3 ft.
		High angle fracturing, pink and green Granodiorite, strongly altered, soft, friable Pink Granodiorite, gneiss		Core lengths 0.3 to 1.0 ft.
	180			
827.4	190	187 to 188 ft. closely broken, iron stained		
		Quartz Diorite, gneiss		
815.4	200			

NPA Form 7(Test) APR. 66 | **PROJECT** Snettisham (Crater Lake) | **HOLE NO.** DH 101

SUMMARY LOG

HOLE NO. DH 101 | **N** 94116 | **E** 88088 | **SHEET** 3 **OF** 3 | **SURFACE ELEV.** 1015.4

PROJECT Snettisham (Crater Lake) | **DRILL DATES: START** 13 OCT 72 **COMP.** 19 OCT 72

DEPTH OF HOLE 232.0 FT | **DEPTH OF OVERBURDEN** 4.5 FT | **DIAM. OF HOLE** NX CORE

ROCK DRILLED 227.5 FT | **CORE RECOVERED** 227.1 FT | **% RECOVERY** 99.8

ANGLE FROM VERT. | **AZIMUTH FROM NORTH** | **COMPILED BY, DATE** CLAYTON RASMUSSEN

DISTANCES: VERTICAL, ; HORIZONTAL,

ELEV 815.4	DEPTH 200	DESCRIPTION OF MATERIALS	% CORE	REMARKS
		Quartz Diorite - as above	14	Core lengths 0.3 to 1.0 ft.
802.4	210	212.5 ft. high angle fracture		
		Granodiorite, pink	15	
798.4	220	Quartz Diorite		
788.4		Granodiorite, pink, gneissic strong	16	
783.4	230			

BOTTOM OF HOLE

DEPTH OF HOLE 232.0 FT
OVERBURDEN 4.5 FT
ROCK CORED 227.5 FT
CORE RECOVERED 227.1 FT
% CORE RECOVERED 99.4
ELEV OF BOTTOM 783.4

Pressure Test Results

From	To	$K(X10^{-2})$
20'	70'	0.0
70'	80'	32.8
80'	110'	0.0
110'	120'	3.5
120'	130'	14.7
130'	140'	50.1
140'	150'	11.2
150'	160'	39.7
160'	170'	49.2
170'	180'	60.5
180'	190'	22.5
190'	230'	0.0

NPA Form 7(Test) APR. 66 | PROJECT Snettisham (Crater Lake) | HOLE NO. DH 101

SUMMARY LOG — HOLE NO. DH 102 — SHEET 1 OF 4

SUMMARY LOG HOLE NO. DH 102	N 93,616 / E 86,380	SHEET 1 OF 4 / SURFACE ELEV 1025.5
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 21 Oct 72	COMP. 27 OCT 72
DEPTH OF HOLE 334 ft.	DEPTH OF OVERBURDEN 0.0 FT	DIAM OF HOLE Nx Core
ROCK DRILLED 334 ft.	CORE RECOVERED 319.4 FT	% RECOVERY 95.6
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 060°	COMPILED BY, DATE
DISTANCES: VERTICAL, 236.2 FT	HORIZONTAL, 236.2 FT	Clayton Rasmussen

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
[illegible]	00		Top of Rock Quartz Diorite, black and white hard and fresh with Gneissic banding and minor jointing, locally some granitic texture 0.0 to 167.5 ft. only fresh breaks due to coring show in core		Core lengths 0.1 to 0.3 ft.
	10				
	20				Core lengths 0.1 to 0.6 ft. Core lengths 0.05 to 1.0 ft.
	30				
	40				Core lengths 0.2 to 5.0 ft.
	50		Quartz Diorite		Core lengths 0.2 to [illegible] ft.
	60				
	70				
	80				Core lengths 0.2 to 1.0 ft.
	90				
954.3	100		Quartz Diorite		

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 102

SUMMARY LOG — HOLE NO. DH 102 — SHEET 2 OF 4

SUMMARY LOG HOLE NO. DH 102	N 93616 / E 86380	SHEET 2 OF 4 / SURFACE ELEV 1025.5
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 21 OCT 72	COMP. 27 OCT 72
DEPTH OF HOLE 334.0 FT	DEPTH OF OVERBURDEN 0.0 FT	DIAM. OF HOLE NX CORE
ROCK DRILLED 334.0 FT	CORE RECOVERED 319.4 FT	% RECOVERY 95.6
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 060°	COMPILED BY, DATE
DISTANCES: VERTICAL, 236.2 FT	HORIZONTAL, 236.2 FT	CLAYTON RASMUSSEN

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
954.3	100		Quartz Diorite - as above		Core lengths 0.2 to 1.0 ft. Core lengths 0.3 to 1.5 ft. Core lengths 0.4 to 2.0 ft.
	110				
	120				
	130				
	140				Core lengths 0.2 to 3.0 ft.
	150		Quartz Diorite 167.5 high angle fracture with high alteration		
	160				Core lengths 0.1 to 0.6 ft.
	170				Core lengths 2.0 to 3.0 ft. Core lengths 0.2 to 1.7 ft.
	180		187.5 high angle fracture close breakage and alteration		
	190				Core lengths 0.7 to 4.0 ft.
884.1	200		196.3 ft. high angle fracture Quartz Diorite		

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DH 102

SUMMARY LOG

HOLE NO. DH 102 | **N** 93616 | **E** 86380 | **SHEET 3 OF 4** | **SURFACE ELEV.** 1025.5

PROJECT Snettisham (Crater Lake)	**DRILL DATES: START** 21 OCT 72 **COMP.** 27 OCT 72	
DEPTH OF HOLE 334.0 FT	**DEPTH OF OVERBURDEN** 0.0 FT	**DIAM. OF HOLE** NX CORE
ROCK DRILLED 334.0 FT	**CORE RECOVERED** 319.4 FT	**% RECOVERY** 95.6
ANGLE FROM VERT. 45°	**AZIMUTH FROM NORTH** 060°	**COMPILED BY, DATE** CLAYTON RASMUSSEN
DISTANCES: VERTICAL, 236.2 FT; **HORIZONTAL,** 236.2 FT		

ELEV	DEPTH	DESCRIPTION OF MATERIALS	REMARKS
884.1	200	Quartz Diorite - as above	Core lengths 0.7 to 4.0 ft.
	210		
873.8		Basalt, black, fine grained dense, fresh 214.5 to 216 ft. closely broken	Core lengths 0.2 to 1.0 ft.
868.9	220	Quartz Diorite	Core lengths 0.4 to 1.5 ft.
863.2	230	Quartz, gray w pyrite	Core lengths 0.1 to 2.0 ft.
860.0		Quartz Diorite Quartz veined 234 to 235 ft. high angle fracture 240 to 242.6 ft. closely broken	Core lengths 0.7 to 2.0 ft. Core lengths 0.1 to 0.3 ft
	240	246.5 to 249 ft. closely broken	Core lengths 0.3 to 2.0 ft.
	250		Core lengths 0.2 to 1.0 ft.
842.7	260	Quartz, gray, Pyritizer	Core lengths 0.1 to 0.6 ft. Large core loss 259.6 to 264.6 ft.
[illegible]		Granodiorite, highly altered, soft friable, closely broken, locally Quartz veined	Core lengths 0.02 to 0.6 ft. White Water Return
	270	Partially altered	White Water Return
		Highly altered	White Water Return
	280		
	290	Partially altered	White Water Return
813.4	300	Granodiorite	Core lengths 0.1 to 1.5 ft.

NPA Form 7(Test) APR. 66 — **PROJECT** Snettisham (Crater Lake) — **HOLE NO.** DH 102

SUMMARY LOG

HOLE NO. DH 102 | **N** 93616 | **E** 86380 | **SHEET 4 OF 4** | **SURFACE ELEV.** 1025.5

PROJECT Snettisham (Crater Lake)	**DRILL DATES: START** 21 OCT 72 **COMP.** 27 Oct 72	
DEPTH OF HOLE 334.0 FT	**DEPTH OF OVERBURDEN** 0.0 FT	**DIAM. OF HOLE** NX CORE
ROCK DRILLED 334.0 FT	**CORE RECOVERED** 319.4 FT	**% RECOVERY** 95.6
ANGLE FROM VERT. 45°	**AZIMUTH FROM NORTH** 060°	**COMPILED BY, DATE** CLAYTON RASMUSSEN
DISTANCES: VERTICAL, 236.2 FT; **HORIZONTAL,** 236.2 FT		

ELEV	DEPTH	DESCRIPTION OF MATERIALS	REMARKS
813.4	300	Granodiorite, partially altered, very closely broken, extensive chloritization 306 to 307 ft. soft Chloritic gouge	Core lengths 0.02 to 0.5 ft. White Water Return
805.2	310	Quartz Diorite, fresh 313 to 317 ft. closely broken	
	320	32? ft. high angle joint Chloritized 326 to 327.5 ft. chloritized closely broken 328 to 334 ft. high angle joint moderately to closely broken	Core lengths 0.2 to 2.0 ft.
789.4	330		LEFT 2.8 FT IN HOLE

BOTTOM OF HOLE

DEPTH OF HOLE 334.0 FT
OVERBURDEN 0.0 FT
ROCK CORED 334.0 FT
CORE RECOVERED 319.4 FT
% CORE RECOVERED 95.6
ELEV OF BOTTOM 789.4 FT

Pressure Test Results

From	To	K(X10^{-5})
10'	20'	830.8 *1
20'	30'	2450.9 *1
30'	40'	2623.2 *1
40'	50'	0.0 *1?
50'	60'	8.6 * ?
60'	70'	106.2 *1?
70'	80'	0.8
80'	100'	0.0
100'	110'	0.8
110'	120'	0.0
120'	130'	37.1 *2
130'	140'	0.8
140'	150'	52.3 *2
150'	170'	0.0
170'	180'	1598.1 *2
180'	190'	138.1 *2
190'	230'	0.0
230'	240'	11.0
240'	250'	13.8
250'	260'	0.7
260'	280'	0.0

*1: tests not valid; test pressure too high. See log - no natural breaks 0.0' to 167.5'

*2: possible slipping packer. See log.

NPA Form 7(Test) APR. 66 — **PROJECT** Snettisham (Crater Lake) — **HOLE NO.** DH 102

SUMMARY LOG — HOLE NO. DDH-103

SUMMARY LOG HOLE NO. DDH-103	N 94271.49 / E [illegible]	SHEET 1 OF 4 / SURFACE ELEV 1086.0
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 10/30/73	COMP. 11/7/73
DEPTH OF HOLE 366.8	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 365.3	CORE RECOVERED 365.3	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH 0°	COMPILED BY, DATE
AREA POWER TUNNEL		C. Rasmussen 12/6/73

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1086.0	0.0	Surface		
		overburden, organic silt, loose rock		
1084.5	1.5	Top of Rock		
		Quartz Diorite, black and white, gneissic		
	10	joint, tight, 35°		
	20			
	30	joint, tight, 35°		
	40			
	50	joint, tight, 35°		
	60	joint, tight, 30°		
	70	joint, tight, 35°		
		joint, tight, 35°		
	80			
		joint, tight, 35°		
	90	joint, tight, 45°		
		joint, tight, rusty, 35°		
		weathered, 91.5' to 92.0', rusty		
		greenstone band, 92.8' to 93.2'		
986.0	100			

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM (CRATER LAKE) — HOLE NO. DDH-103

SUMMARY LOG — HOLE NO. DDH-103

SUMMARY LOG HOLE NO. DDH-103	N 94271.49 / E 88228.32	SHEET 2 OF 4 / SURFACE ELEV 1086.0
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 10/30/73	COMP. 11/7/73
DEPTH OF HOLE 366.8	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 365.3	CORE RECOVERED 365.3	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH 0°	COMPILED BY, DATE
AREA POWER TUNNEL		12/6/73

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
986.0	100	Quartz Diorite, as above		
	110			
	120			
	130			
	140			
	150			core lengths 0.2 to 1.8 ft.
	160	joint, tight, 35°		core lengths 0.3 to 1.4 ft.
	170	joint, sericite coated, 35°		
	180			core lengths to 1.6 ft.
	190			
886.0	200	joint, sericite coated, 40°		core lengths 0.2 to 1.3 ft.

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM (CRATER LAKE) — HOLE NO. DDH-103

SUMMARY LOG

HOLE NO. DDH-103	N 94271.49 / E 88228.32	SHEET 3 OF 4 / SURFACE ELEV. 1086.0
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 10/30/73	COMP. 11/7/73
DEPTH OF HOLE 366.8	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 365.3	CORE RECOVERED 365.3	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH 0°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
886.0	200		Quartz Diorite, light gray, granite		
			joint, tight, 35°		core lengths 0.3 to 1.9 ft.
	210				
	220				
	230				core lengths 0.3 to 3.0 ft.
	240				
	250				core lengths 0.1 to 1.9 ft.
	260		gneissic, pred. black		
	270				
	280		Quartz - carbonate vein, iron stained with pyrite from 282.2' to 286.2'		core lengths 0.4 to 2.5 ft.
	290		joint, slightly altered, 30°		core lengths 0.3 to 2.0 ft.
786.0	300				

NPA Form 7(Test) APR. 66 | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-103

SUMMARY LOG

HOLE NO. DDH-103	N 94271.49 / E 88228.32	SHEET 4 OF 4 / SURFACE ELEV. 1086.0
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 10/30/73	COMP. 11/7/73
DEPTH OF HOLE 366.8	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 365.3	CORE RECOVERED 365.3	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH 0°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
786.0	300		Quartz Diorite, light granitic		
			joint, tight, hematitic, 35°		core lengths 0.1 to 2.4 ft.
	310				
			joint, iron-stained, 45°		
	320				
	330		black and white, gneissic		core lengths 0.4 to 2.8 ft.
	340		joint, iron-stained, 50° joint, iron-stained, 40° joint, iron-stained, 40°		core lengths 0.3 to 2.0 ft.
	350		joint, sericitized with 1/4" band of quartz		
			joints, contact, 50°		
			joint, iron-stained		
	360				
719.2	366.8		joint, iron-stained, 30° joint, longitudinal, slight alt.		
			Bottom of Hole		

NPA Form 7(Test) APR. 66 | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-103

SUMMARY LOG

HOLE NO. DDH-104	N [illegible] / E [illegible]	SHEET 1 OF 5 / SURFACE ELEV. 1113.2
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 9/17/73	COMP. 10/5/73
DEPTH OF HOLE 454.4	DEPTH OF OVERBURDEN 1.7	DIAM. OF HOLE NX
ROCK DRILLED 453.7	CORE RECOVERED 453.7	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH 0°	COMPILED BY, DATE: C. Rasmussen 12/6/73
AREA SURGE TANK		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1113.2	0.0	Surface		
1111.5	1.7	Overburden, organic soil, loose rock		
		Top of Rock		
		Quartz Diorite, white fracture, iron-stained, 15° (from 1.7' to 3.8')		
	10			
	20	black and white		
	30			
	40			
	50	granitic textured, from 48.4' to 55.7'		
	60			
	70	granitic to gneissic, dark		
	80			
	90			
1013.2	100			

NPA Form 7(Test) APR. 68 — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-104

SUMMARY LOG

HOLE NO. DDH-104	N 95454 / E 91400	SHEET 2 OF 5 / SURFACE ELEV. 1113.2
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 9/17/73	COMP. 10/5/73
DEPTH OF HOLE 454.4	DEPTH OF OVERBURDEN 1.7	DIAM. OF HOLE NX
ROCK DRILLED 453.7	CORE RECOVERED 453.7	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH 0°	COMPILED BY, DATE: 12/6/73
AREA SURGE TANK		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1013.2	100	Quartz Diorite, gneissic, black and white		
	110			
	120			
	130	joint, sericite coated, 35°		
	140	fresh fracture, 40°		
	150	fresh fractures, 40°		
		fresh fractures, 25° - 35°		
	160			
	170			
934.4	178.8	Basalt, greenish black		
932.5	180.7	Quartz Diorite, granitic medium gray		
	190			
		fracture, epidote coated (195.2' to 196.8')		
913.2	200			

NPA Form 7(Test) APR. 68 — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-104

SUMMARY LOG

HOLE NO. DDH-104	N 95:54 / E [illegible]	SHEET 3 OF 5 / SURFACE ELEV. 1113.2
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 9/17/73	COMP. 10/5/73
DEPTH OF HOLE 454.4	DEPTH OF OVERBURDEN 1.7	DIAM. OF HOLE NX
ROCK DRILLED 453.7	CORE RECOVERED 453.7	% RECOVERY 100
ANGLE FROM VERT. 0^{o}	AZIMUTH FROM NORTH 0^{o}	COMPILED BY, DATE 12/6/73
AREA SURGE TANK		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
913.2	200		Quartz Diorite, coarse granitic		
	210		fracture, longitudinal, tight		
	220				
	230		fractures, chlorite & sericite coated, 20°		
	240		black & white, marbilized textured, 244.7' to 249.5', predominately black to 261.5'		
	250				
	260		Basalt stringers, dense, greenish black from 261.5' to 262.9'; 264.2' to 266.2'; 266.8' to 267.8' with fused contacts (30° - 40°)		
	270				
	280		Fresh breaks, 40° Basalt stringer, 3/8" thick black, at 284.7', 20° contacts		
	290				
813.2	300				

NPA Form 7(Test) APR. 68 — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-104

SUMMARY LOG

HOLE NO. DDH-104	N 95454 / E 91480	SHEET 4 OF 5 / SURFACE ELEV. 1113.2
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 9/17/73	COMP. 10/5/73
DEPTH OF HOLE 454.4	DEPTH OF OVERBURDEN 1.7	DIAM. OF HOLE NX
ROCK DRILLED 453.7	CORE RECOVERED 453.7	% RECOVERY 100
ANGLE FROM VERT. 0^{o}	AZIMUTH FROM NORTH 0^{o}	COMPILED BY, DATE 12/6/73
AREA SURGE TANK		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
813.2	300		Quartz Diorite, as above		
	310				Artesian flow, 316' to 324'
	320		gneissic texture, dark		
	330				
	340				
	350				
	360		Basalt stringer, 1/2" thick, 10° to 20°		
	370				
	380				
	390				
713.2	400				

NPA Form 7(Test) APR. 68 — PROJECT SNETTISHAM (CRATER LAKE) — HOLE NO. DDH-104

SUMMARY LOG — HOLE NO. DDH-104

N 95454		SHEET 5 OF 5
E [illegible]		SURFACE ELEV. 1113.2
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 9/17/73	COMP. 10/5/73
DEPTH OF HOLE 454.4	DEPTH OF OVERBURDEN 1.7	DIAM. OF HOLE NX
ROCK DRILLED 453.7	CORE RECOVERED 453.7	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH 0°	COMPILED BY, DATE
AREA SURGE TANK		12/6/73

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
713.2	400	Quartz Diorite, as above		
	420	Longitudinal fracture, slight alteration		
658.8	454.4			454.4'
		Bottom of Hole		

NPA Form 7(Test) APR. 68 — PROJECT SNETTISHAM (CRATER LAKE) — HOLE NO. DDH-104

SUMMARY LOG — HOLE NO. DDH-105

N 94135		SHEET 1 OF 4
E 8[illegible]		SURFACE ELEV. 1017.1
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 9/21/73	COMP. 10/7/73
DEPTH OF HOLE 325.9	DEPTH OF OVERBURDEN 2.5	DIAM. OF HOLE NX
ROCK DRILLED 323.4	CORE RECOVERED 322.4	% RECOVERY 99.7
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 330°	COMPILED BY, DATE
AREA POWER TUNNEL		C. Rasmussen 12/6/73

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1017.1	0.0	Surface		
1015.1	2.5	Overburden, organics & rock fragments Top of Rock		set casing to 3.5'
		Quartz Diorite, fresh black and white, gneissic texture		
	13			water loss @ 13.0'
	20	fracture, light iron stain, 60° fracture, light alteration, 20°		
	50	Hornfels, light gray, heavily shattered, Fe stained @ 51.0 & 52.0' fault? Hanging Wall		
974.5	52.0	Granodiorite, highly altered, rotten, pink to white, badly broken from 52.0' to 75.2'		core lengths 0.25' to 0.33'
	70	longitudinal fracture Fault? Footwall		
955.4	75.2	Quartz Diorite, black		
		Hornfels, gray, 78.0' to 78.5'		
949.9	82.0	Granodiorite, coarse texture, pinkish gray		
	90	fracture, highly altered, 45° some kaolin @ 92.6'		
935.2	100			

NPA Form 7(Test) APR. 68 — PROJECT SNETTISHAM (CRATER LAKE) — HOLE NO. DDH-105

SUMMARY LOG

HOLE NO. DDH-105	N 94135	SHEET 2 OF 4
	E [illegible]	SURFACE ELEV 1012.1
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 9/21/73	COMP. 10/7/73
DEPTH OF HOLE 325.9	DEPTH OF OVERBURDEN 2.5	DIAM. OF HOLE NX
ROCK DRILLED 323.4	CORE RECOVERED 322.4	% RECOVERY 99.7
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 330°	COMPILED BY, DATE
AREA POWER TUNNEL		12/6/73

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
935.2	100		Granodiorite, coarse, pinkish gray		
			fractures, slight alteration, 30° - 70°, some Fe staining		
	110		2" rotten quartz vein in rusty zone at 109.5'		
920.4	118.0				
	120		Quartz Diorite, black & white		
917.3	121.8				
			fracture, alteration zone, possible fault Granodiorite, light gray to pink		slow drilling
	130		fractures, closely spaced from 129.5' to 132.5', 50° feldspar alteration forming kaolin (132' to 141.5')		core lengths 0.8' 132' - 136' core lengths 1.0' 136' - 144'
	140				
	150		fracture, tight, 45°		
	160				
884.0	162.5				
881.9	165.6		Quartz Diorite, gneissic, dark		
	170		Granodiorite, pinkish gray		
			Quartz Diorite, 175' to 176'		
870.9	178.5				
	180		Quartz Diorite, black & white fractures, 60°, slight alteration		
	190				
			fracture, 60°, slight alteration		
853.3	200				

NPA Form 7(Test) APR. 66 | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-105

SUMMARY LOG

HOLE NO. DDH-105	N 94135	SHEET 3 OF 4
	E [illegible]	SURFACE ELEV 1012.1
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 9/21/73	COMP. 10/7/73
DEPTH OF HOLE 325.9	DEPTH OF OVERBURDEN 2.5	DIAM. OF HOLE NX
ROCK DRILLED 323.4	CORE RECOVERED 322.4	% RECOVERY 99.7
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 330°	COMPILED BY, DATE
AREA POWER TUNNEL		12/6/73

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
853.3	200		Quartz Diorite, as above		
	210		fractures, 80°, Fe stained		
	220		fracture, 60°, Fe stained		
			fractures, 45°, slight alteration		
	230		fractures, 35°-50°, slight alteration		
	240				
	250		joints, tight, 35°		
	260				
			fracture, 40°, slight alteration		
	270		fracture, 30°, chloritized		
	280				
			fracture, 30°, sericitized		
	290				
771.4	300				

NPA Form 7(Test) APR. 66 | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-105

SUMMARY LOG — HOLE NO. DDH-105

N 93135	E [illegible]	SHEET 4 OF 4
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 9/21/73	COMP. 10/7/73
SURFACE ELEV 1017.1		
DEPTH OF HOLE 325.9	DEPTH OF OVERBURDEN 2.5	DIAM. OF HOLE NX
ROCK DRILLED 323.4	CORE RECOVERED 322.4	% RECOVERY 99.7
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 330°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
771.4	300				
769.7	302.0		Quartz Diorite, as above		
767.2	305.0		Granodiorite, pink pegmatitic		
	310		Quartz Diorite, gneissic, dark 1/4" pyrite band at 309.7'		
	320				
750.1	325.9				325.9'
			Bottom of Hole		

NPA Form 7(Test) APR. 68 | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-105

SUMMARY LOG — HOLE NO. DDH-106

N 93159.	E 91259	SHEET 1 OF 5
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 10/15/73	COMP. 10/26/73
SURFACE ELEV 1039.0		
DEPTH OF HOLE 415.6	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 414.1	CORE RECOVERED 414.1	% RECOVERY 100
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE C. Rasmussen 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1039.0	0.0		Surface		
1037.8	1.5		Overburden organics and loose rock Top of Rock		
			Quartz Diorite, gneissic, dark		
	10				set casing to 9.6'
			fractures, 40°, slight Fe stain		
	20				
			badly crushed zone from 23.4' to 30.0', Fe stained		
	30				
			fracture, 40°, slight alteration		
	40				
	50				
	60				
	70				
973.9	80		fracture, 35°, slight alteration		
973.0			Basalt, black (79.5' to 80.6')		
	90				
957.1	100				

NPA Form 7(Test) APR. 68 | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-106

SUMMARY LOG

HOLE NO. DDH-106	N 95159. / E 91259.	SHEET 2 OF 5 / SURFACE ELEV 1039.0
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 10/15/73	COMP. 10/26/73
DEPTH OF HOLE 415.6	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 414.1	CORE RECOVERED 414.1	% RECOVERY 100
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
857.1	100	Quartz Diorite, gneissic, dark fracture, 40°		
	110			
	120	very coarse white band (125.0' to 126.2')		
	130			
	140			
	150	crushed zone, 150.0' to 150.7' heavy iron staines 150.7' to 152.2' w/0.5' crumbly gouge at base		
	160	fractures, 65°-90°, slight Fe stains w/1/2" iron seam @ 154.0'		
		163.4' to 166.1' - badly shattered, iron stained w/koalinized feldspar in top 6"		
	170	fractures, 45°, slight Fe stains		
	180			
886.1	186.7	Limonite band, 186.5' to 186.7'		
883.2	190.2	Basalt, dark gray, broken		
880.5 / 879.8		Quartz Diorite, gneissic / Basalt, dark gray, w/fractures (193.5' - 194.4')		
875.2	200			

NPA Form 7(Test) APR 66 — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-106

SUMMARY LOG

HOLE NO. DDH-106	N 95159. / E 91259.	SHEET 3 OF 5 / SURFACE ELEV 1039.0
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 10/15/73	COMP. 10/26/73
DEPTH OF HOLE 415.6	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 414.1	CORE RECOVERED 414.1	% RECOVERY 100
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
875.2	200	Quartz Diorite, gneissic		
	210	fractures, 60°, slight alteration		
	220	fractures, 35°-70°, slight alteration		
	230	fractures, slight alteration		
	240			
832.6	250 / 251.9	fractures, 60°-70°, slight alteration		
828.8	256.6	Basalt, fine grained, green-gray to black, mod. fractured		
	260	Quartz Diorite, black & white / fractures, 30°, Fe stained		
		fractures, 35°-45°, slight alteration		
811.9	270 / 277.3	fractures, 45°, Fe stained, highly altered w/kaolin & limonite		
809.3	280.4	Granodiorite, pinkish gray		
		Quartz Diorite, gneissic 30° fracture, slight alteration		
	290			
793.3	300	fractures, 30°-35°, slight alteration		

NPA Form 7(Test) APR. 66 — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-106

SUMMARY LOG — HOLE NO. DDH-106

SUMMARY LOG HOLE NO. DDH-106	N 95159. E 91259.	SHEET 4 OF 5 SURFACE ELEV 1039.0
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 10/15/73	COMP. 10/26/73
DEPTH OF HOLE 415.6	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 414.1	CORE RECOVERED 414.1	% RECOVERY 100
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
793.3	300	Quartz Diorite, gneissic		
		fractures, 25°-45°, slight alteration @ 302.6', 305.8', 314.2', 316.5'		
	310			
	320	greatly altered section w/kaolin, limonite from 323.2' to 324.8' fracture, 80°, slight alteration		
	330			
	340	fractures, 20°-40°, slight alter.		
	350			
	360			
741.3	363.4	Basalt, black w/small phenocrysts quartz diorite (365.8'-366.6')		
737.5	368.1			
	370	Quartz Diorite, gneissic, very fractured from 371.2' to 381.7'		
730.7	376.3	Basalt, dense, black		
728.9	378.5			
	380	Quartz Diorite, black & white		
		fractures, 30°-70°, slight alter.		
	390	Badly crushed zone w/vuggy quartz & yellow-borwn clay gouge @ base from 392.2' to 392.9' highly altered w/limonite (391.4' - 394.9') granodiorite, pink (396.3'-399.3')		
711.3	400			

NPA Form 7(Test) APR. 66 JLW — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-106

SUMMARY LOG — HOLE NO. DDH-106

SUMMARY LOG HOLE NO. DDH-106	N 95159. E 91259.	SHEET 5 OF 5 SURFACE ELEV 1039.0
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 10/15/73	COMP. 10/26/73
DEPTH OF HOLE 415.6	DEPTH OF OVERBURDEN 1.5	DIAM. OF HOLE NX
ROCK DRILLED 414.1	CORE RECOVERED 414.1	% RECOVERY 100
ANGLE FROM VERT. 35°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
711.3	400	Quartz Diorite, as above		
	410	fracture, 40°, slight alteration		
698.5	415.6	Bottom of Hole		415.6'

NPA Form 7(Test) APR. 66 JLW — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-106

SUMMARY LOG — HOLE NO. DDH-107 — SHEET 1 OF 4

SUMMARY LOG HOLE NO. DDH-107	N [illegible] E 90405	SHEET 1 OF 4 SURFACE ELEV. 1000.1
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 11/12/73	COMP. 11/22/73
DEPTH OF HOLE 340.2	DEPTH OF OVERBURDEN 0	DIAM. OF HOLE NX
ROCK DRILLED 340.2	CORE RECOVERED 340.2	% RECOVERY 100
ANGLE FROM VERT. 37°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE
AREA POWER TUNNEL		C. Rasmussen 12/6/73

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1000.1	0.0	Top of Rock Quartz Diorite, light colored, granitic, black in white 60° joint, Fe stained		
				set casing to 3.5'
	10			
	20	joints, 35°-65°, tight iron stain at 21.1'		core lengths 0.3' to 2.0'
		joint, 45°, tight		
	30	joints, 45°-60°, tight		
	40			core lengths 0.1' to 2.3'
	50	joint, 40°, tight		
	60	shear zone, 45° jointing close-tight (56.4' to 61.0') joint, 60°, tight		
	70	joints, tight, 90°, slight Fe stain		core lengths 0.3' to 3.6'
	80	joint, tight, 35° joints, tight, 30°-60°		
	90			core lengths 0.2' to 3.0'
		joints, tight, 45°		
920.2	100			

NPA Form 7(Test) APR. 66 — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-107

SUMMARY LOG — HOLE NO. DDH-107 — SHEET 2 OF 4

SUMMARY LOG HOLE NO. DDH-107	N 94886 E 90405	SHEET 2 OF 4 SURFACE ELEV. 1000.1
PROJECT SHETT. (CRATER LAKE)	DRILL DATES: START 11/12/73	COMP. 11/22/73
DEPTH OF HOLE 340.2	DEPTH OF OVERBURDEN 0	DIAM. OF HOLE NX
ROCK DRILLED 340.2	CORE RECOVERED 340.2	% RECOVERY 100
ANGLE FROM VERT. 37°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE
AREA POWER TUNNEL		12/6/73

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
920.2	100	Quartz Diorite, coarse, black & white		core lengths 0.3' to 2.8'
	110	joints, several		
	120			core lengths 0.3' to 3.8'
		joints, tight, 40°-60°		
	130			core lengths 0.3' to 3.4'
	140	joints, sericitized, 60°		
	150	shear zone, numerous joints, tight (144.0' to 149.5')		core lengths 0.1' to 2.9'
		joints, numerous, broken		
	160			core lengths 0.2' to 2.8'
	170	joint, tight, 30°		
	180			core lengths 0.2' to 2.3'
	190			core lengths 0.3' to 3.2'
840.4	200			

NPA Form 7(Test) APR. 66 — PROJECT SHETTISHAM (CRATER LAKE) — HOLE NO. DDH-107

SUMMARY LOG

HOLE NO. DDH-107	N [illegible] / E [illegible]	SHEET 3 OF 4 / SURFACE ELEV. 1000.1
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 11/12/73	COMP. 11/22/73
DEPTH OF HOLE 340.2	DEPTH OF OVERBURDEN 0	DIAM. OF HOLE NX
ROCK DRILLED 340.2	CORE RECOVERED 340.2	% RECOVERY 100
ANGLE FROM VERT. 37°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
840.4	200	Quartz Diorite, gneissic, medium gray		
	210	joint, epidote & pyrite on surface, 40°		core lengths 0.1 to 2.0'
	220	joint, pyrite w/Fe stain, 30° joint, sericitized, 45°		
		joint, pyritized, 45° w/sericite		core lengths to 2.5'
	230			
		joint, pyritized, 45°		
	240	joint, slick, chloritized		core lengths to 1.4'
	250			core lengths to 2.6'
	260			
		joint, tight, chloritized, 40° joints, tight, Fe stained, 60°		core lengths to 1.0'
	270			
	280	Joints, tight, 45°		
		3" gouge, brown, siliceous @ 284.5'		core lengths to 1.0'
	290	Joints, tight, 30° - 45°		
760.5	300			

NPA Form 7(Test) APR. 66 JLW | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-107

SUMMARY LOG

HOLE NO. DDH-107	N 94886 / E 90405	SHEET 4 OF 4 / SURFACE ELEV. 1000.1
PROJECT SNETT. (CRATER LAKE)	DRILL DATES: START 11/12/73	COMP. 11/22/73
DEPTH OF HOLE 340.2	DEPTH OF OVERBURDEN 0	DIAM. OF HOLE NX
ROCK DRILLED 340.2	CORE RECOVERED 340.2	% RECOVERY 100
ANGLE FROM VERT. 37°	AZIMUTH FROM NORTH 310°	COMPILED BY, DATE 12/6/73
AREA POWER TUNNEL		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
760.5	300	Quartz Diorite, gneissic, dark Joints, tight, Fe stained		core lengths to 1.3'
		Joints, crushed zone @ 305.5'		
	310			core lengths 0.3' to 1.9'
	320	joint, chloritic, 55°		
	330	joint, coated w/biotite, 60°		core lengths to 2.7'
728.4	340.2			340.2
		Bottom of Hole		

NPA Form 7(Test) APR. 66 JLW | PROJECT SNETTISHAM (CRATER LAKE) | HOLE NO. DDH-107

SUMMARY LOG — HOLE NO. DDH-108 — SHEET 1 OF 2

N 93451	E 86209	SURFACE ELEV 1022±	
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 4 Oct 1974	COMP. 10 Oct 1974	
DEPTH OF HOLE 259.3'	DEPTH OF OVERBURDEN 159' water 2' OB	DIAM. OF HOLE NX	
ROCK DRILLED 100.3'	CORE RECOVERED 100.3'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ——	COMPILED BY, Pat DATE 7 Nov 1974	
DISTANCES: VERTICAL, ——	HORIZONTAL, ——		

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1022.0	0.0	Lake Surface		
		water		Hole drilled from float in Crater Lake. Water surface fluctuations up to 3' daily made length of drill runs uncertain. Exact elevation of top of rock unknown. started NX core at 159.0' casing to 168'
863	159	boulder quartz diorite gneiss		
861.0	161.0	Top of Rock		
		Quartz diorite gneiss, grey, lightly weathered, hard, massive; lightly jointed with occasional layers of fine grained mafics.		no pressure tests
	170	broken zone 163.5' to 163.7'		
		solid 170.3' to 176.4'		
		5° clean joint solid 176.4' to 190.8'		
	180			
		185.2' to 188.2', medium grained, light grey acidic gneiss-very faint structure.		
	190	10° clean joint		
		solid 190.8' to 196.1'		
		0° clean joint solid 196.1' to 202.3' strong mafic zone 196.0' to 204.5'		
	200	5° clean joint		
		solid 202.3' to 231.0'		
	210			
		217.3'-healed joint 60°, 0.1 mm chlorite filler		
	220			
	230	4 joints, 10°, 45°, 30° & 10° open 231.4' to 232.0', quartz stringers 10° w minor chlorite in healed joint		
		10°, 5° open joints		
	240	10°, 70° w minor chlorite filler solid 242.6' to 250.3'		
772	250			

SUMMARY LOG — HOLE NO. DDH-108 — SHEET 2 OF 2

N 93451	E 86209	SURFACE ELEV 1022±	
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 4 Oct 1974	COMP. 10 Oct 1974	
DEPTH OF HOLE 259.3'	DEPTH OF OVERBURDEN 159' water	DIAM. OF HOLE NX	
ROCK DRILLED 100.3'	CORE RECOVERED 100.3'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ——	COMPILED BY, Pat DATE 7 Nov 1974	
DISTANCES: VERTICAL, ——	HORIZONTAL, ——		

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
772	250	20°, 10° open joints same as above 251.8' 60° healed joint with pyrite 15° open joint		
762.7	259.3			100.3' rock total 259.3'
		Bottom of Hole		

SUMMARY LOG

HOLE NO. DDH-109	N 93685 / E 86244	SHEET 1 OF 3 / SURFACE ELEV 1022+
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 12 Oct 1974	COMP 19 Oct 1974
DEPTH OF HOLE 277.7'	DEPTH OF OVERBURDEN 76.4' water 6.5' OB	DIAM OF HOLE NX
ROCK DRILLED 194.8'	CORE RECOVERED 194.8'	% RECOVERY 100
ANGLE FROM VERT 0°	AZIMUTH FROM NORTH —	COMPILED BY, Pat DATE 7 Nov 1974
DISTANCES: VERTICAL, —	HORIZONTAL, —	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1022	0.0	Lake surface		
		water		Hole drilled from float in Crater Lake. Water surface fluctuations up to 3' daily made lengths of drill runs uncertain. Exact elevation of top of rock unknown.
945.6	76.4	Medium to coarse grained gravel. Cobbles & boulders - quartz diorite gneiss derived.		Started NX core at 76.4'
	80			
939.1	82.9	Top of Rock		
		Quartz diorite gneiss, black to dark gray, lightly weathered, hard, massive.		Casing to 83.5'
		Disseminated pyrite 83.5'		K0.31X10^{-4}
	90	Closely spaced open joints		
		Disseminated pyrite		K4.0X10^{-4} lost water 92.1'
		Open joints		
		96.2' to 96.5' minor epidote (?) with disseminated pyrite		
	100	open joints 20° 45°		
		solid 100.1' to 116.6		K0.0
	110			
		116.6' ... quartz seam ...		
		open joint ... 40°		
		70° ... light gray gneiss gouge (?) ...		
	120	open joint ... to 70°		
		119.5' minor disseminated pyrite		
		127' open joint in quartz zone		
	130	solid 127.3' to 275.8'		
				K0.01X10^{-4}
	140			
	150			
	160			K0.0 to 276'
852	170			

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DDH-109

SUMMARY LOG

HOLE NO. DDH-109	N 93685 / E 86244	SHEET 2 OF 3 / SURFACE ELEV 1022+
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 12 Oct 1974	COMP. 19 Oct 1974
DEPTH OF HOLE 277.7'	DEPTH OF OVERBURDEN 76.4' water 6.5' OB	DIAM. OF HOLE NX
ROCK DRILLED 194.8'	CORE RECOVERED 194.8'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, Pat DATE 7 Nov 1974
DISTANCES: VERTICAL, —	HORIZONTAL, —	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
852	170	same as above solid 127.3' to 275.8'		
	180			
	190			
	200	disseminated pyrite @202.4'		
		healed 60° joints with 0.1 mm chlorite @ 208.4' & 213.3'		K0.0
	210			
		2mm seam of disseminated pyrite 216.0' to 216.5'		
	220			
	230			
	240			
	250			
	260			
752	270			

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO DDH-109

SUMMARY LOG

HOLE NO. DDH-109	N 93685 / E 86244	SHEET 3 OF 3 / SURFACE ELEV 1022+
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 12 Oct 1974	COMP. 19 Oct 1974
DEPTH OF HOLE 277.7'	DEPTH OF OVERBURDEN 76.4 water, 6.5 OB	DIAM OF HOLE NX
ROCK DRILLED 194.3'	CORE RECOVERED 194.8'	% RECOVERY 100
ANGLE FROM VERT 0°	AZIMUTH FROM NORTH ——	COMPILED BY, Pat DATE 7 Nov 1974
DISTANCES: VERTICAL, —— ; HORIZONTAL, ——		

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
752	270		same as above		K0.0
744.3	277.7		45° w light gray greasy gouge (?) coating		277.7'
	280		Bottom of Hole		

NPA Form 7(Test)

SUMMARY LOG

HOLE NO. DDH-110	N 93599 / E 86220	SHEET 1 OF 2 / SURFACE ELEV 1022+
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 20 Oct 1974	COMP. 25 Oct 1974
DEPTH OF HOLE 271.1'	DEPTH OF OVERBURDEN water 144.0', OB 6.9'	DIAM. OF HOLE NX
ROCK DRILLED 120.2'	CORE RECOVERED 119.7'	% RECOVERY 99.6
ANGLE FROM VERT 0°	AZIMUTH FROM NORTH ——	COMPILED BY, Pat DATE 8 Nov 1974
DISTANCES: VERTICAL, —— ; HORIZONTAL, ——		

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1022.0	0.0		Lake Surface		
			water		Hole drilled from float in Crater Lake. Water surface fluctuations up to 3' daily made lengths of drill runs uncertain. Exact elevation of top of rock unknown.
878.0	144.0		rubble; quartz diorite boulders, cobbles, gravel & mud w/ wood recovered		
871.1	150.9		Top of Rock		
			0°, 5°; Quartz diorite gneiss, gray, lightly weathered, hard, massive. High biotite-hornblende zone 150.9' to 154.2'. Open joints - in strong biotite zone.		Started NX core @ 144.0' casing to 152.5'
					K0.07x10^{-4}
	160		solid 154.2' to 179.2'		
	170				K0.04X10^{-4}
			healed 80° joint w strong muscovite @ 176.4'		
	180		5° on biotite seam @ 179.2'		
			solid 179.2' to 271.1'		
	190				
	200		quartz seam w/chlorite 201.2'		
					K<0.01X10^{-4}
	210				
	220				
	230				
782	240				

NPA Form 7(Test)

SUMMARY LOG

HOLE NO. DDH-110	N 93549 / E 86220	SHEET 2 OF 2 / SURFACE ELEV 1022
PROJECT Snettisham (Crater Lake)	DRILL DATES: START 20 Oct 1974	COMP. 25 Oct 1974
DEPTH OF HOLE 271.1'	DEPTH OF OVERBURDEN water 144.0' / OB 6.9'	DIAM OF HOLE NX
ROCK DRILLED 120.2'	CORE RECOVERED 119.7'	% RECOVERY 99.6
ANGLE FROM VERT 0°	AZIMUTH FROM NORTH —	COMPILED BY, Pat DATE 8 Nov 1974
DISTANCES: VERTICAL, —	HORIZONTAL, —	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
782	240	same as above		
	250			K<0.01x10⁻⁴
	260			
750.9	271.1			271.1'
		Bottom of Hole		left 0.5' in hole
	280			

NPA Form 7(Test) APR 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. DDH-110

SUMMARY LOG

HOLE NO. DH-111	N 93?? 8 / E 86720.3	SHEET 1 OF 3 / SURFACE ELEV 1415.9
PROJECT Crater Lake	DRILL DATES: START 29 July 82	COMP. 21 Aug. 82
DEPTH OF HOLE 747.5	DEPTH OF OVERBURDEN 0.2	DIAM OF HOLE NX
ROCK DRILLED 747.3	CORE RECOVERED 745.9	% RECOVERY 99.8
ANGLE FROM VERT 0°	AZIMUTH FROM NORTH N/A	COMPILED BY, DATE E. Gilbert 9/1/82
DISTANCES: VERTICAL, --	HORIZONTAL, --	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1415.9	0	Surface. QUARTZ DIORITE GNEISS, med. gray, banded, med. grained, hard, lightly weathered, lightly fractured. Fractures clean and rough, occ. iron stains and pyrite on joints, slickensides rare, occ. healed breccia.		0.2' silt at top of rock; RQD 97
	10	Moderately fractured 13.5'-14.1' with gray clay gouge		RQD 95
	20	Gray gouge and pyrite 19.6'; Iron stains and pyrite 21.5'; Aclaic 23'-25'		Lost DWR at 19.6'
	30			RQD 100
	40			RQD 100; 50% DWR
	50	fracture, 20°		RQD 100; 0% DWR
	60			RQD 99; Fracture angles vary from 10°-50° with 30°-45° dominant
	70	fractures, 45°; Moderately fractured 73'-?'		RQD 97
	80			RQD 95; Fracture spacing varies from 0.1'-9.?', avg. 2.4'
	90	Moderately fractured 97.5'-99.5'		RQD 100; RQD 97
1315.9	100			

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO. DH-111

SUMMARY LOG

HOLE NO. DH-111	N 93729.8 / E 86720.3	SHEET 2 OF 8 / SURFACE ELEV. 1415.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1315.9	100	QUARTZ DIORITE GNEISS: idem.		0% DWR
		Slickensides at 107.1', 30°		RQD 89
	110			Fracture spacing 1' ± 107'-113'
	120			RQD 100
		Acidic, high quartz content 125'-131'		
	130	Thin chlorite stringer at 135.1'		
	140			RQD 98
	150			RQD 92
1264.7		Moderately to highly fractured, 151.2'-156.0', occ. gray clay gouge		Fractures near horizontal. Gouge near vertical.
1259.9				
	160	fracture, healed		RQD 99
	170			RQD 97
1243.1				Joints generally clean and rough
		Moderately to highly fractured, 172.8-181.0', yellow-brown stains and slicks.		0% DWR @ 176.0'
1234.9	180			RQD 91
		Moderately to highly fractured at 186.4-194.7', red-brown clay gouge, slicks, and pyrite common.		
1229.5	190			RQD 88
		Fragmented and soft 192.9'-194.7'. High biotite content zone.		0.9' Core loss 193.2'-194.7'
1221.2		Moderately fractured 197.4'-199.7', slicks., gouge, and chlorite common.		RQD 10 Solid core 194.7-197.4', hard
1215.9	200			

NPA Form 7(Test) APR. 68 — PROJECT Crater Lake — HOLE NO. DH-111

SUMMARY LOG

HOLE NO. DH-111	N 93729.8 / E 86720.3	SHEET 3 OF 8 / SURFACE ELEV. 1415.9
PROJECT Crater LAke	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1215.9	200	QUARTZ DIORITE GNEISS: idem.		RQD 97
		Broken zone, vert. fracture		RQD 100
	210	Moderately fractured 213.8'-227.5'		RQD 91
	220			RQD 88
		Shear zone 227.5'-233.5', highly fractured. Gouge 229.9'-230.5' and 232.0'-232.8'		RQD 68
1188.4	230			0.4' core loss 232.0'-232.8' in gouge
				RQD 93
1182.4		Gray clay gouge 235.6'		
				RQD 94
1175.8	240	Shear zone 240.1'-247.6', highly weathered. Yellow-brown clay gouge 240.4-242.1'.		
1168.3	250			RQD 88
		Shattered 251.2'-252.8'		Core broken in thin slivers
		Lightly fractured and lightly weathered below 252.8'.		
	260			
	270			RQD 100; 253.1'-293.8'
	280			
	290			RQD 91
1115.9	300			

NPA Form 7(Test) APR. 68 — PROJECT Crater Lake — HOLE NO. DH-111

SUMMARY LOG

HOLE NO. Dh-111	N 93729.8 / E 86720.3	SHEET 4 OF 8 / SURFACE ELEV. 1415.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1115.9	300		QUARTZ DIORITE GNEISS: idem.		0% DWR
	310				
	320				
	330				Core lengths range up to 30 feet.
	340				
	350				RQD 100; 304.1-405.4
	360				
	370				
	380				
	390				
1015.9	400				

NPA Form 7(Test) APR. 66 | PROJECT Crater Lake | HOLE NO. DH-111

SUMMARY LOG

HOLE NO. DH-111	N 93729.8 / E 86720.3	SHEET 5 OF 8 / SURFACE ELEV. 1415.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1015.9	400		QUARTZ DIORITE GNEISS: idem.		
	410				RQD 96; core lengths 1.0' to 3.0'
			Chlorite seam 0.02' thick at 416.0'		
	420				RQD 100; 413.7'-434.3'
	430				
			fracture, pyrite trace; fracture, clay trace		
	440				RQD 96
			fracture, chlorite trace		Joint spacing varies from 0.2'-13.3'; avg. 2.6'
	450				
958.6			Granite dikes 457.3'-460.7' and 463.5'-469.0'		
955.2	460				RQD 100; 444.6'-475.6'
952.4					
			Muscovite coated joint (60°) at 466.9'		Joint is smooth
946.9	470				
					10% DWR
	480				RQD 93
	490				RQD 100; 485.5'-505.5'
915.9	500				

NPA Form 7(Test) APR. 66 | PROJECT Crater Lake. | HOLE NO. DH-111

SUMMARY LOG

HOLE NO. DH-111	N 93729.8 / E 86720.3	SHEET 6 OF 8 / SURFACE ELEV. 1415.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
915.9	500		QUARTZ DIORITE GNEISS: idem.		
	510				Drill rate at 5 min/ft.
					No natural breaks between 492.9-590.4′
	520				
	530				
	540				RQD 100; 505.5-585.4′
	550				
	560				
	570				
	580				
	590				RQD 98
815.9	600				RQD 100

NPA Form ?(Test)

SUMMARY LOG

HOLE NO. DH-111	N 93729.8 / E 86720.3	SHEET 7 OF 8 / SURFACE ELEV. 1415.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
815.9	600		QUARTZ DIORITE GNEISS: idem.		RQD 90
			0.05′ gray gouge at 603.2′ minor shear zone 601.8-604.0′		Lost 0.1′ core between 603.1′ and 603.3′
	610				RQD 96
	620				RQD 100
	630				RQD 94
	640				Joint spacing varies from 0.1-15.1′; avg. 3.1′
					RQD 100; 631.9-662.8′
	650				
	660				
	670				RQD 97
	680				RQD 100; 672.9-693.6′
			High muscovite content and calcite joint fillers 687.0-690.0′		
	690				RQD 96
715.9	700				

NPA Form ?(Test)

SUMMARY LOG — HOLE NO. DH-111

N 93729.8 / E 86720.3	SHEET 8 OF 8	SURFACE ELEV. 1415.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE 747.5	DEPTH OF OVERBURDEN 0.2	DIAM. OF HOLE NX
ROCK DRILLED 747.3	CORE RECOVERED 745.9	% RECOVERY 99.8
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH N/A	COMPILED BY, DATE
DISTANCES: VERTICAL, --	HORIZONTAL, --	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
715.9	700	QUARTZ DIORITE GNEISS: idem. joint, low angle		
	710	joint, low angle		RQD 100; 704.0'-725.7'
	720			Joint spacing varies from 0.4'-21.8'; avg. 9.7'
	730	Joints, low angle		RQD 96
	740			RQD 100; 734.9'-80H
668.4'	747.5			747.5'
	750	BOTTOM OF HOLE		0.1' left in hole

Depth of hole 747.5'
Thickness of overburden 0.2'
Rock cored 747.3'
Core recovered 745.9'
% Core recovered 99.8'

Pressure Tests

From	To	K(Ft./Min.)
3'	21'	19.4×10^{-4}
20'	38'	4.3×10^{-4}
38'	92'	0.0
92'	110'	1.5×10^{-5}
110'	146'	0.0
350'	747.5'	1.85×10^{-8}

SUMMARY LOG — HOLE NO. DH-112

N 93767.6 / E 86703.6	SHEET OF	SURFACE ELEV 1409.3
PROJECT Crater Lake	DRILL DATES: START 10 Sept. 82	COMP. 2 Oct.82
DEPTH OF HOLE 602.1	DEPTH OF OVERBURDEN 1.2	DIAM. OF HOLE NX
ROCK DRILLED 600.9	CORE RECOVERED 598.7	% RECOVERY 99.6
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 150°	COMPILED BY, DATE
DISTANCES VERTICAL, 521.4	HORIZONTAL, 301.1	P. Galbraith 12/6/82

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1409	0.0	Surface		
1408.3	1.2	PEAT; Top of Rock		
		QUARTZ DIORITE GNEISS: med. gray, banded, med. grained, lightly weathered, lightly fractured. Fractures generally cleanand rough, occ. iron stains and pyrite on joints, slickensides rare. occ. healed breccia.		RQD 9?
	10			
	20			Solid core 24.6-79.?
	30			Joint spacing varies from 0.2'-55 ?; avg. 5.?
	40			RQD 100
	50			
	60			Solid core 30.?-105.4
	70			
	80			RQD 97; Lost drill water pressure at 80 feet DWR not lost.
	90			RQD 100, 84.3-144.4
1322	100			

SUMMARY LOG

HOLE NO. DH-112

N 93767.6	E 86703.6	SHEET 2 OF 7
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		SURFACE ELEV. 1409.3

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1322.7	100	QUARTZ DIORITE GNEISS: idem.		
	110			
	120			RQD 100; 84.3'-144.4'
	130			
		Joint, 45°		Joint spacing 135'-189' varies from 0.2'-9.0'; avg. 3.0'
	140	Joints, 30°-40°		
	150	Calcite and muscovite on joint 148'		RQD 96
		Joints, 35°-60°		
	160			
	170			
	180			RQD 100; 154.3'-214.4'
	190			Solid core 189.5'-219.0'
1236.1	200			

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO. DH-112

SUMMARY LOG

HOLE NO. DH-112

N 93767.6	E 86703.6	SHEET 3 OF 7
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		SURFACE ELEV. 1409.3

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1236.1	200	QUARTZ DIORITE GNEISS: idem.		Solid core 189.5'-218.9'
				RQD 100; 154.3'-214.4'
	210			
	220			RQD 92
1217.9	221.5	Dessimated pyrite common below 220'		
1213.4	226.2	Shear zone 221.5'-226.2', highly weathered, tanto brown clay gouge common. High biotite content, very soft.		Solid core 226.4'-247.6'
	230			RQD 88
	240			
	250			RQD 100; 234.6'-274.2'
	260			Joint spacing 247.6'-300' varies from 0.2'-9.2'; avg. 1.9'
	270	Core acidic 269.1'-281.7'. Fractures with calcite coating common.		
	280			RQD 98
	290			RQD 97
				RQD 100
1149.5	300			

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO.

SUMMARY LOG — SHEET 4 OF 7

SUMMARY LOG HOLE NO. DH-112	N 93767.6 / E 86703.6	SHEET 4 OF 7 / SURFACE ELEV. 1409.3
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1149.5	300	QUARTZ DIORITE GNEISS: idem.		RQD 100
	310			RQD 95
	320			RQD 100; 314.2'-334.6'
	330			Joint spacing varies from 0.1'-11.5'; avg. 2.0'
	340			RQD 97
	350	Heavy iron stain 347.2'-348.5'		RQD 87
	360			RQD 100
1095.5	362.3	APLITE DIKE, grey-brown		362.3'
1094.1	364.0			364.0'
	370			RQD 97
	380			RQD 100
	390			RQD 88
1062.9	400	0.01' Calcite joint filler @ 397.8'		RQD 97

NPA Form 7(Test) APR. 66 — PROJECT Crater Lake — HOLE NO. DH-112

SUMMARY LOG — SHEET 5 OF 7

SUMMARY LOG HOLE NO. DH-112	N 93767.6 / E 86703.6	SHEET 5 OF 7 / SURFACE ELEV. 1409.3
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1062.9	400	QUARTZ DIORITE GNEISS: idem. Slickensides 405.2' (50°)		Joint spacing 400'-434' varies from 0.1'-5.8'; avg. 1.4'
	410			RQD 100
	420			RQD 91
1043.8	422.0	RHYOLITE DIKE: light gray, hard, fine grained, mod. to lightly fractured.		
	430			RQD 100
1033.4	434.0	QUARTZ DIORITE GNEISS: idem.		
	440	Shear zone 422'-462', highly weathered, mod. to highly fractured, occ. fragmented, altered, occ. clay gouge. "Baked Zone"		RQD 62
1022.8	446.5	Fault, near vertical, with gray gouge 446.5' to 454.6'		
	450			RQD not significant, rock is soft to very soft.
1015.6	454.6			
	460			RQD 90
	470	Moderately to highly fractured to 467'.		Joint spacing 467'-482' varies from 0.2'-8.4'; avg. 3.6' RQD 92
	480	Moderately fractured 482'-491'		RQD 94
	490	Lightly fractured below 491'		RQD 95
976.3	500			

NPA Form 7(Test) APR. 66 — PROJECT Crater Lake — HOLE NO. DH-112

SUMMARY LOG

HOLE NO. DH-112	N 93767.6 / E 86703.6	SHEET 6 OF 7 / SURFACE ELEV 1409.3
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV 976.3	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	500		QUARTZ DIORITE GNEISS: Idem.		RQD 98
	510				RQD 89
			Iron stains 512-513		
			Moderately weathered in fractures 514.4-514.7		Solid core 514.7-526.9
	520				
	530				
					RQD 100 514.7-564.6
	540				
	550				Solid core 540-570
	560				
	570				RQD 96
			Iron stains 575.2		Stress relief fracturing 573.6-574.0
	580				RQD 100 574.6-BOH
	590				Solid core 593.2-BOH
889.7	600				

NPA Form

SUMMARY LOG

HOLE NO. DH-112	N 93767.6 / E 86703.6	SHEET 7 OF 7 / SURFACE ELEV 1409.3
PROJECT Crater Lake	DRILL DATES: START 10 Sept. 82	COMP. 2 Oct. 82
DEPTH OF HOLE 602.1	DEPTH OF OVERBURDEN 1.2	DIAM. OF HOLE NX
ROCK DRILLED 600.9	CORE RECOVERED 598.7	% RECOVERY 99.6
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 150°	COMPILED BY, DATE
DISTANCES: VERTICAL, 521.4	; HORIZONTAL, 301.1	

ELEV 889.7	DEPTH 600	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
887.9	602		QUARTZ DIORITE GNEISS: Idem.		602.1' Left 0.1' in hole
	610		BOTTOM OF HOLE		

Depth of hole	602.1
Thickness of overburden	1.2
Rock cored	600.9
Core recovered	598.7
% Core recovered	99.6

Pressure Tests

From	To	K Ft./Min.
10'	232'	2.55×10^{-4}
232'	282'	7.6×10^{-4}
282'	432'	17.0×10^{-4}
432'	602.2'	4.0×10^{-6}

NPA Form

SUMMARY LOG — HOLE NO. DH-113

N 93773.3		SHEET 1 OF 5
E 86699.5		SURFACE ELEV. 1409.4
PROJECT Crater Lake	DRILL DATES: START 6 Oct. 82	COMP. 14 Oct. 82
DEPTH OF HOLE 392.2	DEPTH OF OVERBURDEN 2.0	DIAM. OF HOLE NX
ROCK DRILLED 390.2	CORE RECOVERED 387.5	% RECOVERY 99.3
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 330°	COMPILED BY, jat DATE 9 Jul 83
DISTANCES: VERTICAL, 339.7	; HORIZONTAL, 196.1	

ELEV 1409.4	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
		OVERBURDEN: muskeg		2.0'
1407.7		QUARTZ DIORITE GNEISS: med. gray, banded med. grained, hard, slightly weathered, lightly fractured. Fractures generally clean and rough; occ. iron stains and pyrite on joints. Slickensides rare; occ. healed breccia.		RQD 79
	10			RQD 87
		Moderately to highly fractured 2.0'-14.3'		Joint spacing 2.0'-14.3' varies from 0.2'-2.0'; avg. 0.6'
	20			RQD 98
	30			RQD 100
		Moderately to highly fractured 32.0'-40.2'		
	40	Small shear 37.6'-38.5'; fragmented, oxidation on joints; no gouge resent.		RQD 86
	50			RQD 94
				Joint spacing 14.3'-100' varies from 0.1'-9.6'; avg 1.5'
	60	Highly fractured 59.0'-59.8'		RQD 90
	70			RQD 96
	80	Moderately fractured 84.4'-86.9'		RQD 99
	90	Moderately to highly fractured 92.8'-149.3'		RQD 92
1322.8	100			RQD 97

NPA Form APR 66 7(Test) — PROJECT Crater Lake — HOLE NO. DH-113

SUMMARY LOG — HOLE NO. DH-113

N 93773.3		SHEET 2 OF 5
E 86699.5		SURFACE ELEV. 1409.4
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV 1322.8	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1322.8	100	Strong oxidation and iron stains 100.4-102.4'		
		Yellow-brown clay gouge 105.0'-105.4'		RQD 80
	110	Strong oxidation and iron staining 109-110'		RQD 72
	120	SHEAR ZONE: mod. to highly fractured 100.4'-143.8'; gray calcareous gouge common. Fragmented, mod. soft 120'-121.6'		RQD 89
		Strong oxidation with 0.01' silicified gouge 126.6'-126.8'		RQD 92
1295.6	130	Strong oxidation, clay common with slickensides 131.4'-132.8' and 134.8'-136.2'		
1291.4	140	Calcified red-brown gouge 141.4'-141.6'		RQD 87
1284.9				
	150	QUARTZ DIORITE GNEISS: idem.		RQD 95
		Closely spaced fractures 157.6'-159.0'		Lost DWR 158.0'
	160			RQD 98
				70% DWR 158'-165'
		Moderately to highly fractured 165.4-175.5'		0% DWR 167'-80H
	170			RQD 83
	180			RQD 92
	190			RQD 94
		Small shear 192.8'-194'; trace of green-brown gouge.		
1236.2	200	Moderately to highly fractured 192.8'-197.5'		

NPA Form APR 66 7(Test) — PROJECT Crater Lake — HOLE NO. DH-113

SUMMARY LOG — SHEET 1 OF 5

HOLE NO. DH-113	N 93773.3 / E 86699.5	SHEET 1 OF 5 / SURFACE ELEV. 1409.4
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1236.2	200	QUARTZ DIORITE GNEISS: Idem		RQD 98
	210	40° joint mica coated, smooth, greasy		RQD 95
				RQD 100
	220	Moderately fractured 221.9'-227.6'		RQD 89
	230			RQD 94
	240			
	250			RQD 100; 235.2'-275.1'. Joint spacing varies from 0.9'-12.1'; avg. 5.0'
	260			
	270			
	280	Moderately weathered, highly fractured with minor red-brown gouge 277.3'-278.1'		RQD 92
	290			RQD 94
1149.6	300			

NPA Form 7(Test) PROJECT HOLE NO. DH-113

SUMMARY LOG — SHEET 4 OF 5

HOLE NO. DH-113	N 93773.3 / E 86699.5	SHEET 4 OF 5 / SURFACE ELEV 1409.4
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1149.6	300	QUARTZ DIORITE GNEISS		
	310			RQD 100; 295.1'-335.2' Joint spacing varies from 1.3-19.0; avg. 5.6'
	320			
	330			
	340	Moderately fractured 343.0'-345.3'		RQD 96
	350	Healed shear 348.9'-349.5', highly fractured		RQD 91
				45° joint with minor chlorite 355.2'
	360	Moderately fractured 363.0'-365.4'		RQD 95; 45° smooth joint with high biotite concentration at 365.4'
	370	Moderately fractured 372.0'-50H alcite common on joints, iron stains common.		RQD 96
	380			RQD 97
				RQD 90
1071.5	390			390.2
		BOTTOM OF HOLE		
	400			

NPA Form 7(Test) PROJECT HOLE NO. DH-113

SUMMARY LOG

HOLE NO. DH-113 — N 93773.3 — E 86699.5 — SHEET 5 OF 5 — SURFACE ELEV 1409.4

PROJECT Crater Lake — DRILL DATES: START 6 Oct 82 — COMP. 14 Oct 82

DEPTH OF HOLE 392.2′	DEPTH OF OVERBURDEN 2.0′	DIAM OF HOLE NX
ROCK DRILLED 390.2′	CORE RECOVERED 387.5′	% RECOVERY 99.3
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 330°	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV | DEPTH | GRAPHIC LOG | DESCRIPTION OF MATERIALS | % CORE | REMARKS

Depth of Hole	392.2′
Thickness of Overburden	2.0′
Rock Cored	390.2′
Core Recovered	387.5′
% Recovered	99.3

Pressure Tests

From	To	? Ft./Min.
20′	90′	.04x10^{-4}
90′	190′	23.15x10^{-4}
190′	290′	5.56x10^{-4}
290′	392.2′	5.96x10^{-5}

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO. DH-113

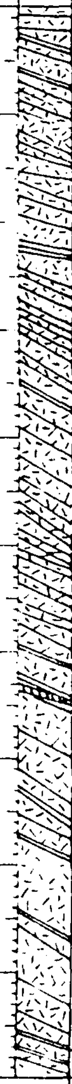
SUMMARY LOG

HOLE NO. DH-114 — N 93731.0 — E 86934.0 — SHEET 1 OF 7 — SURFACE ELEV 1297.3

PROJECT Crater Lake — DRILL DATES: START 6 Oct. 82 — COMP. 17 Oct. 82

DEPTH OF HOLE 592.1	DEPTH OF OVERBURDEN 0.0	DIAM OF HOLE NX
ROCK DRILLED 592.1	CORE RECOVERED 591.8	% RECOVERY 99.9
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 315°	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	PAT 11-4-82

ELEV 1297.3 | DEPTH | GRAPHIC LOG | DESCRIPTION OF MATERIALS | % CORE | REMARKS



Depths: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 — ELEV 1210

QUARTZ DIORITE GNEISS: med. gray, banded, med. grained, hard, lightly weathered, lightly fractured. Fractures generally clean and rough; occ. iron stains and pyrite on joints, slickensides rare, occ. healed breccia.

Moderately to lightly fractured 0.0′-69.5′

0.01′ clay gouge @ 62.7′

Thin calcite seam @ 97.6′

Remarks: RQD 88, RQD 95, RQD 86, RQD 99, RQD 9?, RQD 95, RQD 39, RQD 90, RQD 99, RQD 96

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO. DH-114

SUMMARY LOG
HOLE NO. DH-114

N 93731.0	E 86934.0	SHEET 2 OF 7
PROJECT Crater Lake	DRILL DATES: START	COMP.
SURFACE ELEV. 1297.3		
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1210.7	100	QUARTZ DIORITE GNEISS: idem.		
				RQD 100
	110			
				RQD 98
	120			
	130			
	140			RQD 100; 119.7'-170.9'
				Joint spacing varies from 0.4'- 7.2'; avg. 2.3'
1166.4	150	Minor red-brown clay gouge with slickensides at 151.1'		Lost DWR at 151.1'
				Regain 90% DWR @ 153'
	160			
	170			
				RQD 98
	180			
				RQD 100
	190			
				RQD 95
1124.1	200			

NPA Form 7(Test)

SUMMARY LOG
HOLE NO. DH-114

N 93731.0	E 86934.0	SHEET 3 OF 7
PROJECT Crater Lake	DRILL DATES: START	COMP.
SURFACE ELEV. 1297.3		
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1124.1	200	QUARTZ DIORITE GNEISS: idem.		
				RQD 96
	210			
				RQD 95
1109.5		Shear zone 216.8'-227.3', highly weathered, mod.fractured, hydrothermal alt. common, gray clay gouge common 217-221', 0.5' gray clay mylonite 221'-227.3'		
	220			
				RQD 93
1100.5		Slickensides @ 228.0'		
	230	Greasy 60° joint @ 231.2'		
		Moderately fractured 235.5'-239.4'		RQD 93
	240			
				RQD 97
	250			
	260	50° joint, biotite,greasy @ 264'		
		40° joint; biotite,flacky greasy at 267'		RQD 100; 250.4'-411.7'
	270			Joint spacing varies from 0.3'-31.1'; avg. 7.0'
	280			
				Trace calcite and chlorite @ 286'
	290			
1037.3	300			

NPA Form 7(Test)

SUMMARY LOG — SHEET 4 OF 7

SUMMARY LOG HOLE NO. DH-114	N 93731.0 / E 86934.0	SHEET 4 OF 7 / SURFACE ELEV. 1297.3
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1037.5	300		QUARTZ DIORITE GNEISS		Trace of calcite and chlorite @ 306.4'
	310				Trace of calcite and chlorite @ 317'
	320				
	330				Trace of calcite and chlorite @ 331.5'
					Chlorite @ 335'
	340				RQD 100; 250.4'-411 7'
996.4					347.5'
	350		GRANITE		Acidic zone
985.9	360				359.6'
					Solid core 355.7'-387.1'
	370				
	380		Healed shear (10^0) @ 387.1'		
	390				
950.9	400				Trace of calcite and pyrite @ 398'

NPA Form 7(Test) APR. 66 — PROJECT Crater Lake — HOLE NO. DH-114

SUMMARY LOG — SHEET 5 OF 7

SUMMARY LOG HOLE NO. DH-114	N 93731.0 / E 86934.0	SHEET 5 OF 7 / SURFACE ELEV 1297.3
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES VERTICAL, ; HORIZONTAL,		

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
950.9	400		QUARTZ DIORITE GNEISS: idem.		
	410				RQD 97
	420				Widely spaced joints with traces of calcite and chlorite
	430				Occ smooth joints in high biotite concentrations
					Solid core 432.4'-455.2'
	440				RQD 100, 421.[illegible]'-451.7' Joint spacing varies from 0.4'-22.3', avg. 4.3'
	450				RQD 98
	460				
	470				
	480				RQD 100: 461.[illegible]'-521.8' Joint spacing varies from 0.4'-12.7', avg. 1.9'
	490				
864.3	500				

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO. DH-114

SUMMARY LOG

HOLE NO. DH-114	N 93731.0 / E 86934.0	SHEET 6 OF 7 / SURFACE ELEV 1297.3
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES VERTICAL,	HORIZONTAL,	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	500		QUARTZ DIORITE GNEISS: idem.		
					Joints have traces of calcite and chlorite, occ. micas
	510				
	520				
841.6			Hydrothermal alteration with traces of clay gouge and calcite; highly fractured 526.2-527.2		RQD 87
	530				
					RQD 100
	540				
					RQD 90
	550				
					[illegible]
	560				
806.1					
803.8	570		Shear zone 56[illegible]-569.[illegible], mod. fractured to fragmented, calcite, chlorite and gray clay gouge common		
					RQD 100
	580				
					RQD 96
784.5	590				592.1′
			BOTTOM OF HOLE		
	600				

NPA Form 7(Test)

SUMMARY LOG

HOLE NO. DH-114	N 93731.0 / E 86934.0	SHEET 7 OF 7 / SURFACE ELEV 1297.3
PROJECT Crater Lake	DRILL DATES: START 6 Oct. 82	COMP. 17 Oct. 82
DEPTH OF HOLE 592.1′	DEPTH OF OVERBURDEN 0.0′	DIAM. OF HOLE NX
ROCK DRILLED 592.1′	CORE RECOVERED 591.3′	% RECOVERY 99.9
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 315°	COMPILED BY, DATE
DISTANCES: VERTICAL, 512.8′	HORIZONTAL, 296.1′	

ELEV | DEPTH | GRAPHIC LOG | DESCRIPTION OF MATERIALS | % CORE | REMARKS

Depth of hole	592.1′
Thickness of overburden	0.0,
Rock cored	592.1,
Core recovered	591.3′
% Core recovered	99.9

Pressure Tests

From	To	K.Ft./Min.
6′	116′	9.66×10^{-6}
116′	136′	4.46×10^{-5}
136′	216′	11.9×10^{-5}
216′	236′	1.65×10^{-5}
240′	592.2′	0.0

NPA Form 7(Test)

SUMMARY LOG

HOLE NO. DH-115	N 95300.4 / E 91992.3	SHEET 1 OF 7 / SURFACE ELEV 803.9
PROJECT Crater Lake	DRILL DATES: START 9 Sept 82	COMP. 29 Sept 82
DEPTH OF HOLE 650.1'	DEPTH OF OVERBURDEN 3.4'	DIAM. OF HOLE NX
ROCK DRILLED 646.7'	CORE RECOVERED 645.3'	% RECOVERY 99.2
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 300°	COMPILED BY, DATE: Pat 11/8/82
DISTANCES: VERTICAL, 459.7'	HORIZONTAL, 459.7'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
803.9	0.0	Surface		
801.5	3.4	OVERBURDEN: silt, high organic. Top of Rock		3.4
		QUARTZ DIORITE GNEISS: medium gray, banded medium grained, lightly weathered, lightly fractured. Fractures generally clean and rough, occ. iron stains and pyrite on joints, slicks. rare, occ. healed breccia, occ. basalt dikes.		RQD 100: 3.4'-32.6' Joint spacing varies from 0.5-9.2', avg. 5.3
		Highly fractured 33.0'-34.2'		Sample removed 37.2'-37.3'
		Basalt dike 37.2'-37.3', see below		RQD 90
776.5	38.8			
775.5	40.1	BASALT: gray-green, porphoritic, hard		
		QUARTZ DIORITE GNEISS: idem.		RQD 84
		Highly fractured to shattered 44.2'-45.6'		3.4'-100', joint spacing 0.1-12', avg. 1.5'; does not include moderately and highly fractured zones.
				RQD 90
				RQD 100: 61.6'-82.6' Joint spacing varies from 0.4-4.6', avg. 1.1'
		Highly fractured 86.7'-87.4'		RQD 95
		Moderately fractured 93.5'-97.2'		RQD 89
733.2	100			

NPA Form 7(Test) APR. 66 — PROJECT Crater Lake — HOLE NO. DH-115

SUMMARY LOG

HOLE NO. DH-115	N 95300.4 / E 91992.3	SHEET 2 OF 7 / SURFACE ELEV 803.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
733.2	100	Shear zone: 100.6'-102.6', fat, soft red-brown clay gouge 100.6'-100.9' and 101.6'-101.8'; thermal alt. 101.8'-102.6', highly frac., mod. weathered.		RQD 82
		Highly fractured 104.2'-106.7' some iron staining		Joint spacing 106.7'-133.1' varies from 0.8'-7.8', avg. 5.5'
		QUARTZ DIORITE GNEISS: idem.		RQD 35
				RQD 98
709.8				RQD 88
		Moderately to highly fractured 133.1'-166.3', pyrite common, joints clean and moderately rough.		RQD 90
		yellow-brown coating 157.6'		RQD 85
667.3				RQD 90
		Moderately fractured 166.3'-196.1'		RQD 99
				RQD 96
				RQD 100
662.5	200			

NPA Form 7(Test) APR. 66 — PROJECT Crater Lake — HOLE NO. DH-115

SUMMARY LOG

HOLE NO. DH-115	N 95300.4 / E 91992.3	SHEET 3 OF 7 / SURFACE ELEV 803.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
662.5	200	QUARTZ DIORITE GNEISS: idem.		RQD 100
		Moderately fractured 206.1'-208.6'		RQD 96
	210			
		Highly fractured 214.6'-215.6'		RQD 94
	220			Solid core 219.3'-238.0'
	230			
	240			RQD 100, 222.6'-292.6'
	250			Solid core [illegible]
	260			
	270			
	280			Solid core 278.2'-294.[illegible]'
	290			RQD 88
591.8	300			

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO. DH-115

SUMMARY LOG

HOLE NO. DH-115	N 95300.4 / E 91992.3	SHEET 4 OF 7 / SURFACE ELEV 803.9
PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
591.8 / 590.8	300	Shear zone: 301.4'-303.6', sandy gray-green gouge @301.8' (0.01' thick) mod. weathered 301.6'-302.7' hydrothermal alt. and calcite common, highly fractured		
589.2				RQD 90
	310	QUARTZ DIORITE GNEISS: idem.		Solid core 303.6'-315.8'
	320			RQD 100
	330			RQD 94
		Moderately fractured 331.0'-339.4'		RQD 99
564.2	339.0			
	340	BASALT: same as page 1, lightly fractured; gray clay gouge 343.1'-343.3'		
559.0	346.4			
	350	QUARTZ DIORITE GNEISS: idem.		RQD 98
	360			RQD 100
				Joint spacing 339.4'-394.4' varies from 0.1'-3.9', avg. 2.0'
	370			RQD 98
	380			RQD 99
	390			RQD 97
				Solid core 394.4'-435.0'
521.1	400			

NPA Form 7(Test) APR 66 — PROJECT Crater Lake — HOLE NO. DH-115

SUMMARY LOG

HOLE NO. DH-115 | N 95300.4 | E 91992.3 | SHEET 5 OF 7 | SURFACE ELEV 803.9

PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
521.1	400	QUARTZ DIORITE GNEISS: idem.		Solid core 394.4'-435.0'
	410			RQD 100; 392.6'-432.6' 2 natural breaks @ 394.0' and 394.4'
	420			
	430			
496.3		Moderately to highly fractured 435.0'-441.1'. Thin calcareous clay coating on joint at 435.0'. Occ. pyrite and pale red-brown calcite coatings on joints.		Lost DWR at 435', artesian head to surface 30', surface flow rate at 2 gpm
492.0	440			RQD 20
				Solid core 44[illegible]-456.6'
	450			RQD 100; 43[illegible]-461.3'
	460			
				Solid core 465.[illegible]-4[illegible]9.6' RQD 99
	470			
				RQD 93
	480			
				Solid core 485.4'-492.8' RQD 94
	490			
				RQD 100; 492.1'-522.1'
450.3	500			

NPA Form 7(Test) APR 66 | PROJECT Crater Lake | HOLE NO. DH-115

SUMMARY LOG

HOLE NO. DH-115 | N 95300.4 | E 91992.3 | SHEET 6 OF 7 | SURFACE ELEV 803.9

PROJECT Crater Lake	DRILL DATES: START	COMP.
DEPTH OF HOLE	DEPTH OF OVERBURDEN	DIAM. OF HOLE
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
450.3	500	QUARTZ DIORITE GNEISS: idem.		Solid core 503.3'-516.2'
	510			
	520			
		Highly fractured 525.0'-526.3'		RQD 92
429.1	530	Shear zone 530.0'-538.6', mod. to highly frac. 530'-533.4' and 536.4'-538.6', fragmented with occ. calcareous gray-green gouge 533.4'-536.4'; red-brown calcite coating common on joints.		Lost 0.5' core 533.4'-536.4'
423.1				RQD 51
	540			
				RQD 94
	550			
				RQD 97
	560			
				RQD 98
	570			
		Moderately fractured 576.5'-578.6', minor blotchy iron stains and minor calcite coatings on joints.		RQD 93, Lost 0.2' core
	580			
				RQD 100; 580.4'-BOH
	590			Solid core 592.3'-605.5'
379.6	600			

NPA Form 7(Test) APR 66 | PROJECT Crater Lake | HOLE NO. DH-115

SUMMARY LOG

HOLE NO. DH-115

N 95300.4	E 91992.3	SHEET 7 OF 7
SURFACE ELEV 803.9		
PROJECT Crater Lake	DRILL DATES: START 9 Sept 82	COMP. 28 Sept. 82
DEPTH OF HOLE 650.1	DEPTH OF OVERBURDEN 3.4	DIAM. OF HOLE NX
ROCK DRILLED 646.7	CORE RECOVERED 645.3	% RECOVERY 99.3
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 300°	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
379.6	600		QUARTZ DIORITE GNEISS: dem.		
	610				
	620				Solid core 618.6'-649.1'
					RQD 100, 530.4'-BOH
	630				
	640				
344.2	650				650.1'
			BOTTOM OF HOLE		Left 0.?' in hole

BOTTOM OF HOLE

Depth of hole	650.1'
Thickness of overburden	3.4'
Rock cored	646.7'
Core recovered	645.3'
% Core recovered	99.3

Pressure Tests

From	To	K,Ft./Min.
16'	216'	2.38×10^{-4}
226'	295'	2.17×10^{-6}
296'	336'	4.8×10^{-6}
336'	346'	5.24×10^{-5}
346'	436'	4.1×10^{-5}
446'	516'	7.06×10^{-5}
526'	536'	3.5×10^{-4}
536'	566'	1.95×10^{-5}
576'	586'	7.4×10^{-5}
590'	650.1'	2.4×10^{-5}

NPA Form 7(Test) APR 66 PROJECT Crater Lake HOLE NO. DH-115

SUMMARY LOG

HOLE NO. DH-116

N 93645	E 86124	SHEET 1 OF 1
SURFACE ELEV. 1021.8		
PROJECT Crater Lake, Snettisham	DRILL DATES: START 18 Jul 84	COMP. 20 Jul 84
DEPTH OF HOLE 228.1'	201.3' water; 26.8' Lake Bottom Debris	DIAM. OF HOLE NQ
ROCK DRILLED 0.0'	CORE RECOVERED 18.9'	% RECOVERY 71
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, Sat DATE 19 Oct 84
DISTANCES: VERTICAL, 0.0'	; HORIZONTAL, 0.0'	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1021.8	0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 18 Jul 84.
820.5	200 / 201.3				201.3' (18 Jul 84)
			OVERBURDEN: Boulders, cobbles and gravel, Quartzdiorite gneiss lithology, gray, lightly weathered.		100% DWR 207.6'-209.3' 1% DWR Remainder of Hole
	210		Boulders vary from 2.5' to 10.6' thick (drilled dimensions)		NW CSG to 211.4'
	220				
793.7	228.1				228.1'
	230		Bottom of Hole		3 Boxes of core Bedrock not drilled; drill rods very tight due to shift of material. Hole abandoned; moved to DH-116A. Hole not pressure tested - overburden. Lost NQWL barrel, 10' NQ Rod, 10' NW Csg.

NPA Form 7(Test) APR 66 PROJECT Snettisham (Crater Lake) HOLE NO. DH-116

SUMMARY LOG — HOLE NO. OH-116A

N 93 641	E 86 144	SHEET 1 OF 1 — SURFACE ELEV. 1021.1
PROJECT Snettisham/Crater Lake	DRILL DATES: START 20 Jul 84	COMP. 23 Jul 84
DEPTH OF HOLE 241.6'	190.6' water / 17.9' Lake bottom debris	DIAM. OF HOLE NCQ
ROCK DRILLED 33.1'	CORE RECOVERED 12.1' OB / 33.1' rock	% RECOVERY 68 OB / 100 rock
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Sot 19 Oct 1984
DISTANCES: VERTICAL, 0.0'	HORIZONTAL, 0.0'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1021.1	0 (180)	CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevations given as of 20 Jul 84. 190.6' (20 Jul 84)
830.5	190.6 (200)	OVERBURDEN: Boulders, cobbles, gravels and wood; quartz diorite gneiss lithology, gray lightly weathered. Bounders range from 1.2' to 7.2' thick (drilled dimensions)		Water depth fluctuates. NW CSG to 195.4' 0% DWR 208.5
812.6	208.5 (210, 220, 230, 240)	TOP OF ROCK QUARTZ DIORITE GNEISS; gray, hard lightly weathered, lightly fractured. Solid core from 211.0' to 239.3'. Pyrite and biotite at 231.3'. Healed fractures at 232.6' and 239.1'.		RQD 100 0% DWR No natural breaks 211.0' to 239.3' 241.6'
779.5	241.6	BOTTOM OF HOLE		5 Boxes of Core Packers would not seal. No effective pressure tests Hole not grouted. Lost 193' HW Csg.

NPA Form 7(Test) APR. 66 — PROJECT Snettisham (Crater Lake) — HOLE NO. OH-116A

SUMMARY LOG — HOLE NO. OH-117

N 93656	E 86120	SHEET 1 OF 2 — SURFACE ELEV. 1020.9
PROJECT Snettisham/Crater Lake	DRILL DATES: START 27 Jul 84	COMP. 9 Aug 84
DEPTH OF HOLE 296.1'	206.9' water / 15.5' Lake bottom debris	DIAM. OF HOLE NCQ
ROCK DRILLED 73.7'	CORE RECOVERED 6.6' OB / 71.2' Rock	% RECOVERY 43 OB / 97 Rock
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Sot 19 Oct 1984
DISTANCES: VERTICAL, 0'	HORIZONTAL, 0'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.9	0 (200)	CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevations given as of 27 Jul 84. 16.9' difference in lake bottom elevation measured from quill to stern. 206.9' (27 Jul 84)
814.0	206.9 (210, 220)	OVERBURDEN; rock flour and sand, soft to 214.9 ft COBBLES, GRAVEL AND SMALL boulders (214.9' to 222.4') boulders to 2.5 feet thick.		No sample recovered. NW CSG 220.8' 222.4'
798.5	222.4 (230, 240, 250, 260, 270, 280)	TOP OF ROCK QUARTZ, DIORITE GNEISS; gray, hard lightly weathered, lightly fractured. Closely spaced low angle joints 229.5' to 230.0'. One 35° joint at 230.0' Granite dike 246.3' to 247.5'		No natural fractures, 236.0 to BOH. RQD 100
730.9	290			

NPA Form 7(Test) APR. 66 — PROJECT Snettisham/Crater Lake — HOLE NO. OH-117

SUMMARY LOG — HOLE NO. DH-117

N 9365 6	E 86120	SHEET 2 OF 2	SURFACE ELEV. 1020.9
PROJECT	DRILL DATES: START 27 Jul 84	COMP. 9 Aug 84	
DEPTH OF HOLE 296.1'	206.9' water / 15.5' LAKE BOTTOM DEBRIS	DIAM. OF HOLE NCQ	
ROCK DRILLED 73.7'	CORE RECOVERED 6.6' OB / 71.2' Rk	% RECOVERY 43 OB / 97 Rock	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Sat 19 Oct 1984	
DISTANCES: VERTICAL, 0'	; HORIZONTAL, 0'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	REMARKS
730.9	290	QUARTZ DIORITE GNEISS; same as above.	Healed fractures between 285' and 293'.
724.8	296.1		296.1 (2.4' left in hole)
	300	BOTTOM OF HOLE	13 BOXES OF CORE Note: Hole drilled to 261.6'. Rods pulled back & hole cemented to prevent caving. A new hole was apparently started at 224.1 This was most likely due to a small overburden shift This log is a composite of both holes. Lost core barrel and 80 ft of NQ drill rods in hole. Attempted pressure test, but packer set in overburden. Hole grouted.

NPA Form 7(Test)

SUMMARY LOG — HOLE NO. DH-118

N 9364 6	E 86111	SHEET 1 OF 1	SURFACE ELEV. 1021.8
PROJECT Snettisham/Crater Lake	DRILL DATES: START 21 Aug 84	COMP. 23 Aug 84	
DEPTH OF HOLE 261.7'	204.5' water / 24.2' Lake Bottom Debris	DIAM. OF HOLE NCQ	
ROCK DRILLED 33.0'	CORE RECOVERED 4.5' OB / 32.0' rock	% RECOVERY 19 OB / 97 rock	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Sat 19 Oct 1984	
DISTANCES: VERTICAL, 0'	; HORIZONTAL, 0'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	REMARKS
1021.8	0	CRATER LAKE	Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 21 Aug 84.
	200		
817.3	204.5		204.5' (21 Aug 1984)
	210, 220	OVERBURDEN; soft to 220.9' depth, rock flour. Gravel, cobbles & small boulders; quartz diorite gneiss lithology. Boulders to 1 ft thick.	samples recovered
793.1	228.7	TOP OF ROCK	228.7'
	230, 240, 250, 260	QUARTZ DIORITE GNEISS; gray, hard lightly weathered, lightly fractured. Trace of gouge at 236.0'; healed fractures at 230.9', 241.5', and 245.9'. Granite dike, 244.0' - 245.6' Healed breccia zone from 254.1' to 254.8'.	NW CSG to 230.2' No natural fractures, 236.0' to BOH. RQD 100 0% DWR
760.1	261.7		261.7'
	270, 280, 290	BOTTOM OF HOLE	no pressure tests possible 4 boxes of core. Hole not grouted. Lost NQWL barrel, 232' NW Csg, 200' HW Csg. and tap.

NPA Form 7(Test)

SUMMARY LOG

HOLE NO. DH-119

N	93,655
E	86,168
SHEET	1 OF 1
SURFACE ELEV.	1020.7'
PROJECT	Snettisham/Crater Lake
DRILL DATES: START	31 Aug 84
COMP.	2 Sep 84
DEPTH OF HOLE	184.4'
	163.8' Water; 12.1' Lake Bottom Debris
DIAM. OF HOLE	NCO
ROCK DRILLED	8.5'
CORE RECOVERED	6.2' OB; 8.5' Rock
% RECOVERY	51 OB; 100 Rock
ANGLE FROM VERT.	0°
AZIMUTH FROM NORTH	
COMPILED BY, DATE	Jat 21 Oct 84
DISTANCES: VERTICAL	0'
HORIZONTAL	0'

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.7	0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevation vary. Surface elevation given as of 1 Sep 84.
	150				10.6' difference in lake bottom elevation measured from bow to stern.
	160				
856.9	163.8				163.8' (1 Sep 84)
			OVERBURDEN: TILL, Gray, dense, damp to semi-dry (163.8 to 169.4')		0.7' Spl. retained.
	170		Boulder and gravel (169.4' to 175.9') Boulders to 4.2' thick		NW CSG to 171.1'
844.8	175.9		TOP OF ROCK		175.9'
	180		QUARTZDIORITE GNEISS, gray, hard, lightly fractured, lightly weathered		RQD 100
			Healed fractures between 181.4' and 184.1'.		0% DWR
836.3	184.4				184.4'
			BOTTOM OF HOLE		2 BOXES OF CORE
	190				Overburden exploration; no pressure tests
	200				Hole not grouted.

NPA Form 7(Test) APR. 66 — **PROJECT** Snettisham/Crater Lake — **HOLE NO.** DH-119

SUMMARY LOG

HOLE NO. DH-120

N	93 684
E	86 201
SHEET	1 OF 1
SURFACE ELEV.	1020.5
PROJECT	SNETTISHAM/CRATER LAKE
DRILL DATES: START	3 Sep 84
COMP.	4 Sep 84
DEPTH OF HOLE	141.4'
	133.2' WATER; SEE REMARKS
DIAM. OF HOLE	NQ
ROCK DRILLED	8.2'
CORE RECOVERED	8.2'
% RECOVERY	100%
ANGLE FROM VERT.	0°
AZIMUTH FROM NORTH	
COMPILED BY, DATE	Jat 21 Nov 84
DISTANCES: VERTICAL	0.0'
HORIZONTAL	0.0'

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.5	0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 3 Sep 84.
	100				Attempted overburden sampling through 1.1' of rock flour. Pushing sampler shifted barge; drilling started on bare rock face at elevation 887.3'
	110				
	120				NW CSG to elevation 888.6' HW CSG to elevation 887.9'
	130				
887.3	133.2		TOP OF ROCK		133.2'
			Quartz diorite gneiss, gray, hard lightly weathered; moderately fractured to 135.9'; solid core 135.9' to bottom of hole.		0% DWR
					RQD 95
879.1	141.4				141.4'
			Bottom of Hole		1 Box of Core
					No pressure tests
					Hole not grouted

NPA Form 7(Test) APR. 66 — **PROJECT** CRATER LAKE/SNETTISHAM — **HOLE NO.** DH-120

SUMMARY LOG — HOLE NO. DH-121

SUMMARY LOG HOLE NO. DH-121	N 93 723 / E 86 201		SHEET 1 OF 1 / SURFACE ELEV. 1020.3
PROJECT SNETTISHAM/CRATER LAKE	DRILL DATES: START 5 Sep 84	COMP. 6 Sep 84	
DEPTH OF HOLE 139.3'	WATER 119.7' / LAKE BOTTOM DEBRIS 8.8'		DIAM. OF HOLE NQ
ROCK DRILLED 10.4'	CORE RECOVERED 8.7' DEBRIS / 10.2' ROCK		% RECOVERY 99% OB / 98% RK
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH		COMPILED BY, DATE: Sat 19 Nov 84
DISTANCES: VERTICAL, 0.0'	; HORIZONTAL, 0.0'		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.3	0.0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 5 Sep 84.
	110				
900.6	119.7		GRAVEL, COBBLES, AND SMALL BOULDERS quartz diorite gneiss lithology, iron stained fracture surfaces.		119.7' 0% DWR
891.8	128.5		TOP OF ROCK		128.5'
			QUARTZ DIORITE GNEISS: gray, hard, lightly fractured, lightly weathered; fracture surfaces are rough, 30-45°		0% DWR RQD 98
881.0	138.9		BOTTOM OF HOLE		138.9' 2 BOXES OF CORE. Hole not pressure tested. Hole not grouted

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM/CRATER LAKE — HOLE NO. DH-121

SUMMARY LOG — HOLE NO. DH-122

SUMMARY LOG HOLE NO. DH-122	N 93 632 / E 86 218		SHEET 1 OF 1 / SURFACE ELEV. 1020.0
PROJECT SNETTISHAM/CRATER LAKE	DRILL DATES: START 7 Sep 84	COMP. 7 Sep 84	
DEPTH OF HOLE 147.7'	DEPTH OF OVERBURDEN WATER 130.6' / 6.2' OB		DIAM. OF HOLE NQ
ROCK DRILLED 10.9'	CORE RECOVERED 0.6' OB / 10.9' RK		% RECOVERY 10% OB / 100% RK
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH		COMPILED BY, DATE: LMH 9 Nov 84
DISTANCES: VERTICAL, 0.0'	; HORIZONTAL, 0.0'		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.0	0.0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 7 Sep 84.
	120				
889.4	130.6		OVERBURDEN: soft, rock flour		130.6' Overburden 1.5'.
			GRAVEL, COBBLES, SMALL BOULDERS: quartz diorite gneiss lithology		
883.2	136.8		QUARTZ DIORITE GNEISS: gray, hard, lightly weathered.		TOP OF ROCK 136.8'
	140		Two semi-parallel fractures at 141.4', 30°, semi-rough surfaces.		0% DWR RQD 100. Solid core from 141.6' to 147.7'.
872.3	147.7				147.7'
	150		BOTTOM OF HOLE		2 BOXES OF CORE. No pressure tests. Hole not grouted

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM/CRATER LAKE — HOLE NO. DH-122

SUMMARY LOG HOLE NO. DH-123

N 93 702	E 86 279	SHEET 1 OF 1
PROJECT Crater Lake/Snettisham		SURFACE ELEV. 1019.9'
DRILL DATES: START 8 Sep 84	COMP. 8 Sep84	
DEPTH OF HOLE 54.3'	44.6' Water; 0.5 Lake Bottom debris	DIAM. OF HOLE NQ
ROCK DRILLED 9.2'	CORE RECOVERED 9.2'	% RECOVERY 100%
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Tat 19Nov84
DISTANCES: VERTICAL, 0.0'	; HORIZONTAL, 0.0'	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1019.9	0		CRATER LAKE		Hole drilled from barge on lake Water depth & lake surface elevations vary. Surface elevation given as of 8 Sep 84.
	40				
975.3	44.6'				44.6'
974.8	45.1		OVERBURDEN: Soft, sand.		Overburden classified as sand by feel only - no samples recovered.
	50		QUARTZ DIORITE GNEISS: gray, hard, lightly weathered, solid core 46.1' to bottom of hole. Iron staining on top of rock surface.		0% DWR RQD 100
965.6'	54.3				54.3'
	60		Bottom of Hole		1 Box of core No pressure tests. 13.8' difference in lake bottom elevation measured from quill to stern. Hole not grouted.
	70				

NPA Form 7(Test) APR. 66 | PROJECT CRATER LAKE/SNETTISHAM | HOLE NO. DH-123

SUMMARY LOG HOLE NO. DH-124

N 93 666	E 86 198	SHEET 1 OF 1
PROJECT CRATER LAKE/SNETTISHAM		SURFACE ELEV. 1019.6
DRILL DATES: START 14 Sep 84	COMP. 14 Sep 84	
DEPTH OF HOLE 153.5'	DEPTH OF OVERBURDEN Water 134.7'; 0.0'	DIAM. OF HOLE NQ
ROCK DRILLED 18.8'	CORE RECOVERED 18.1'	% RECOVERY 96.3
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Tat 20Nov84
DISTANCES: VERTICAL, 0.0'	; HORIZONTAL, 0.0'	

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1019.6	0.0'		CRATER LAKE SURFACE WATER		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 14 Sep 84
	100				
	110				
	120				
	130				
884.9	134.7		TOP OF ROCK 134.7'		NW Casing set to el. 884.9'
	140		QUARTZ DIORITE GNEISS: gray, hard, lightly weathered, lightly fractured or jointed Vertical fractures between 143.7' and 145.3', 146.4' and 148.9', 149.1' and 150.1'.		0% DWR RQD 68 Healed fractures between 137.5' and 141.2'.
	150				
866.1	153.5				153.3'
			BOTTOM OF HOLE		2 Boxes of Core No pressure tests. Hole not grouted.

NPA Form 7(Test) APR. 66 | PROJECT CRATER LAKE/SNETTISHAM | HOLE NO. DH-124

SUMMARY LOG

HOLE NO. DH-125 | **N** 93 445 | **E** 86 137 | **SHEET** 1 **OF** 1 | **SURFACE ELEV.** 1021.2'

PROJECT SNETTISHAM/CRATER LAKE | **DRILL DATES: START** 16 Sep 84 **COMP.** 20 Sep 84

DEPTH OF HOLE 273.4' | Water 214.7' Lake Bottom Debris 10.8' | **DIAM. OF HOLE** NQ

ROCK DRILLED 47.9' | **CORE RECOVERED** 7.0' OB 47.2' ROCK | **% RECOVERY** 65% OB 99% RK

ANGLE FROM VERT. 0° | **AZIMUTH FROM NORTH** 0° | **COMPILED BY,** LMH **DATE** 8 Nov 84

DISTANCES: VERTICAL, ; HORIZONTAL,

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1021.2	0.0'	CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 16 Sep 84.
	210			
806.5	214.7			214.7'
	220	GRAVELS, COBBLES, AND SMALL BOULDERS: Quartz diorite gneiss lithology, some iron staining, moderately fractured rock.		NW Casing to 221.7'.
795.7	225.5	TOP OF ROCK		225.5'
	230	QUARTZ DIORITE GNEISS: gray, hard, lightly weathered, lightly fractured.		0% DWR RQD 100
		Granitic zone between 235.9' and 238.7'. Healed fractures between 235.9' and 238.7'.		
	240			
		Semi-parallel fractures, 30-45°, between 246.9' and 248.8'.		
	250			
	260			
	270			
747.8	273.4			273.4'
		BOTTOM OF HOLE		5 BOXES OF CORE No pressure tests. Hole grouted, two packers and 10' NQ rod grouted in Hole. 10' push sampler lost.

NPA Form 7(Test) PROJECT SNETTISHAM/CRATER LAKE HOLE NO. DH-125

SUMMARY LOG

HOLE NO. DH-126 | **N** 93 441 | **E** 86 161 | **SHEET** 1 **OF** 2 | **SURFACE ELEV.** 1020.0

PROJECT SNETTISHAM/CRATER LAKE | **DRILL DATES: START** 23 Sep 84 **COMP.** 27 Sep 84

DEPTH OF HOLE 271.6' | **DEPTH OF OVERBURDEN** Water 193.7' 9.2' | **DIAM. OF HOLE** NQ

ROCK DRILLED 68.7' | **CORE RECOVERED** 1.3' OB 68.7' RK | **% RECOVERY** 26% OB 100% RK

ANGLE FROM VERT. 0° | **AZIMUTH FROM NORTH** | **COMPILED BY,** **DATE** 21 Nov '84

DISTANCES: VERTICAL, 0.0' **; HORIZONTAL,** 0.0'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.0	0.0'	SURFACE (CRATER LAKE) WATER		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 23 Sep 84.
	190			
826.3	193.7	BOTTOM OF LAKE		193.7'
	200	OVERBURDEN: Boulders, cobbles, & gravel, quartz diorite gneiss lithology, gray, slightly weathered.		Start NQ coring at 198.1' Rounded gravels at 198.7' and 202.7'.
817.1	202.9	TOP OF ROCK		202.9'
		QUARTZ DIORITE GNEISS: gray, hard, lightly weathered, lightly fractured		80-90% DWR RQD 97
	210	Three closely spaced fractures at 213.4'; healed breccia at 214.5'.		
	220	Two closely spaced fractures, approximately 30°, at 219.0'. Three closely spaced fractures, 30-40°, at 221.0'.		
	230			
	240	Two closely spaced fractures, 45°, at 241.0'. Complex fractures at 245.4' with slicks and iron staining.		
	250	Healed fracture, 48°, at 253.4'.		
760.0	260			

NPA Form 7(Test) PROJECT SNETTISHAM/CRATER LAKE HOLE NO. DH-126

SUMMARY LOG — HOLE NO. DH-126

N 93 441 / E 86 161	SHEET 2 OF 2	SURFACE ELEV. 1020.0
PROJECT SNETTISHAM/CRATER LAKE	DRILL DATES: START 23 Sep 84	COMP. 27 Sep 84
DEPTH OF HOLE 271.6'	DEPTH OF OVERBURDEN WATER 193.7', 9.2'	DIAM. OF HOLE NQ
ROCK DRILLED 68.7'	CORE RECOVERED 1.3' OB, 68.7' ROCK	% RECOVERY 26% OB, 100% RK
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Kat 21 Nov '84
DISTANCES: VERTICAL, 0.0'	HORIZONTAL, 0.0'	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
760.0	260		QUARTZ DIORITE GNEISS, as above. Solid core from 257.9' to 271.6'. Healed fault, 263.1' to 264.1'. Healed breccia zone from 265.2' to 269.8'.		
748.4	270 271.6				271.6'
			BOTTOM OF HOLE		8 boxes of core Hole not grouted.
			Pressure test data 28 Sep 84		

Depth	Pressure	K (ft/Min)
26.2-77.9'	25 psi	0
26.2-77.9'	38 psi	0

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM/CRATER LAKE — HOLE NO. DH-126

SUMMARY LOG — HOLE NO. DH-127

N 93 441 / E 86 190	SHEET 1 OF 1	SURFACE ELEV. 1019.7'
PROJECT Snettisham/Crater Lake	DRILL DATES: START 29 Sep 84	COMP. 29 Sep 84
DEPTH OF HOLE 194.4'	170.9' Water, 7.0' Lake Bottom Debris	DIAM. OF HOLE NQ
ROCK DRILLED 16.5'	CORE RECOVERED 16.2'	% RECOVERY 98
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Jat 21 Nov '84
DISTANCES: VERTICAL, 0.0'	HORIZONTAL, 0.0'	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1019.7'	0		CRATER LAKE BOTTOM OF LAKE 170.9'		Hole drilled from barge on Lake Water depth and lake surface elevations vary. Surface elevation given as of 29 Sep 84; started hole with lake level at elevation 1019.7' and ended with lake level at elevation 1019.9'.
848.8'	170 170.9'		OVERBURDEN: Soft to 4.5'; gravelly 4.5' to 6.6'; soft 6.6' to 7.0' TOP OF ROCK 177.9'		No overburden samples retained; description is by feel as drill washed thru.
841.8'	177.9' 180'		QUARTZ DIORITE GNEISS: Gray, hard, lightly weathered, lightly fractured. Soft 179.4' to 179.5' and 183.0' to 183.1' Biotite rich 185.6' to 187.4'		HW CSG to elevation 852.4' NW CSG to elevation 848.4' 0% UWR RQD 98
825.3'	190 194.4'				194.4'
			Bottom of Hole		2 boxes of core No pressure tests. Hole not cemented.

NPA Form 7(Test) APR. 66 — PROJECT Snettisham, Crater Lake — HOLE NO. DH-127

SUMMARY LOG — HOLE NO. DH-128

N 93 439	E 86 241	SHEET 1 OF 1	SURFACE ELEV. 1020.1'
PROJECT Crater Lake/Snettisham	DRILL DATES: START 30 Sep 84	COMP. 3 Oct 84	
DEPTH OF HOLE 140.0'	>17.8' Lake Bottom debris; 122.2' Water	DIAM. OF HOLE NQ	
ROCK DRILLED 0.0'	CORE RECOVERED 12.7'(OB)	% RECOVERY 91%	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Jat 21Nov84	
DISTANCES: VERTICAL, 0.0'	HORIZONTAL, 0.0'		

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.1	0.0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 30 Sep 84.
					HW CSG to elevation 922.6'
897.9	122.2		OVERBURDEN: boulders, cobbles, and gravel recovered; quartz diorite gneiss lithology. Boulder 122.2' to 128.8'		122.2' NW CSG to elevation 898.0'
880.1	140.0		Bottom of Hole		140.0' Overburden shifted while drilling NW CSG. Hole abandoned in overburden. Lost 10' NW CSG. 2 boxes of core. No pressure tests. Attempted spudding on cliff face in 110.4' of water. NQ bbl. "walked" down face to 122.2' of water at start of drilling. Horizontal component unknown. Hole not cemented.

NPA Form 7(Test) PROJECT CRATER LAKE/SNETTISHAM HOLE NO. DH-128

SUMMARY LOG — HOLE NO. DH-128A

N 93,445	E 86,243	SHEET 1 OF 1	SURFACE ELEV. 1021.5
PROJECT Snettisham/Crater Lake	DRILL DATES: START 9 Oct 84	COMP. 10 Oct 84	
DEPTH OF HOLE 155.3	111.5' water; 1.0' Lake bottom debris	DIAM. OF HOLE NQ	
ROCK DRILLED 42.8'	CORE RECOVERED 0.7' OB; 41.7 rock	% RECOVERY 70% OB; 97.4% rock	
ANGLE FROM VERT. 0	AZIMUTH FROM NORTH	COMPILED BY, DATE Jat 22Nov'84	
DISTANCES: VERTICAL,	HORIZONTAL,		

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1021.5	0.0		Crater Lake		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 9 Oct 84. HW CSG to el. 912.1' NQ CSG to el. 910.3'
910.0	111.5		BOTTOM OF LAKE. OVERBURDEN: Large cobbles & gravel.		
909.0	116.6		QUARTZ DIORITE GNEISS: gray, hard, moderately fractured, lightly weathered. Open fractures with rock flour common (119.3', 125.1', 131.7', 145.7, 151.9'). Open fractures at 136.1, 139.5, 144.7, 145.0. Open fractures. Highly fractured 136.0'-139.8'. Highly fractured 141.5'-148.1'		Open fractures at 119.3' may require removal of rock
866.2	155.3		BOTTOM OF HOLE		Hole not grouted.

NPA Form 7(Test) PROJECT HOLE NO.

SUMMARY LOG — HOLE NO. DH-129

N 93 405 / E 86 252	SHEET 1 OF 1	SURFACE ELEV. 1020.6'
PROJECT SNETTISHAM/CRATER LAKE	DRILL DATES: START 4 Oct 84	COMP. 6 Oct 84
DEPTH OF HOLE 107.1'	DEPTH OF OVERBURDEN WATER 88.3', 12.3'	DIAM. OF HOLE NQ
ROCK DRILLED 6.5'	CORE RECOVERED 6.0' RK, 11.5' OB	% RECOVERY 93% RK, 94% OB
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, JMH DATE 14Nov84
DISTANCES: VERTICAL, 0'	HORIZONTAL, 0'	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.6	0.0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 4 Oct 84. Washed through gravels to El. 932.1'. 88.3'
932.3	88.3		OVERBURDEN: Cobbles and boulders, quartz diorite gneiss lithology; 6.5' boulder between El. 922' and 931'; TOP OF ROCK		iron-stained surfaces with some rock flour. 100.6'
920.0	100.6		QUARTZ DIORITE GNEISS: gray, hard moderately fractured; fracture surfaces stained with iron.		RQD 77 107.1'
913.5	107.1		BOTTOM OF HOLE		2 BOXES OF CORE Lost hole 129 when changing bits. Began hole 129A approximately 1 ft away from 129. HW CSG to El. 933.1 NW CSG to El. 932.7 Hole not grouted.

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM/CRATER LAKE — HOLE NO. DH-129

SUMMARY LOG — HOLE NO. DH-129A

N 93 405 / E 86 252	SHEET 1 OF 1	SURFACE ELEV. 1020.4'
PROJECT SNETTISHAM/CRATER LAKE	DRILL DATES: START 6 Oct 84	COMP. 6 Oct 84
DEPTH OF HOLE 124.3'	DEPTH OF OVERBURDEN WATER 88.6', 10.3'	DIAM. OF HOLE NQ
ROCK DRILLED 25.4'	CORE RECOVERED 10.0' OB, 24.5' RK	% RECOVERY 97% OB, 96% RK
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, JMH DATE 14Nov84
DISTANCES: VERTICAL, 0'	HORIZONTAL, 0'	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.4	0.0		CRATER LAKE		Hole drilled from barge on lake. Water depth and surface elevations vary. Surface elevation given as of 6 Oct 84. 88.6'
931.8	88.6		OVERBURDEN: Boulder (88.6-98.1'), with gravel and fragments (98.1'-98.9') TOP OF ROCK		0% OWR 98.9'
921.5	98.9		QUARTZ DIORITE GNEISS: gray, hard, lightly weathered, lightly fractured. Complex fractures between 99.4' and 100.2'. Closely spaced fractures, 104.6' to 105.9', with iron stains and rock flour. Fractures spaced from 0.2' to 2.6' between 106.6' and BOH. Biotite zone from 107.6' to 120.6'.		RQD 89 Discontinuity in core at 101.0 is a rebound joint. Fracture surfaces semi-rough, with iron stain and some rock flour. 124.3'
896.1	124.3		BOTTOM OF HOLE		4 BOXES OF CORE No pressure tests. Hole not grouted.

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM/CRATER LAKE — HOLE NO. DH-129A

SUMMARY LOG — HOLE NO. DH-130

N	93 441
E	86 279
SHEET	1 OF 1
SURFACE ELEV.	1020.8
PROJECT	CRATER LAKE/SNETTISHAM
DRILL DATES: START	7 Oct 84
COMP.	7 Oct 84
DEPTH OF HOLE	94.4'
DEPTH OF OVERBURDEN	WATER 67.1' 4.1'
DIAM. OF HOLE	NQ
ROCK DRILLED	23.2'
CORE RECOVERED	0.9' DEBRIS 23.2' ROCK
% RECOVERY	100%
ANGLE FROM VERT.	0°
AZIMUTH FROM NORTH	
COMPILED BY, DATE	Jat 20 Nov 84
DISTANCES: VERTICAL	0.0'
HORIZONTAL	0.0'

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.8	0.0		CRATER LAKE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 7 Oct 84.
	60				HW CSG to El. 963.4' NW CSG to El. 961.6
953.7	67.1'				67.1'
	70		OVERBURDEN: Loose, gravelly material and small boulders.		Start coring at 70.2'
949.6	71.2'		TOP OF ROCK		
			QUARTZ DIORITE GNEISS: gray, hard, lightly weathered, moderately fractured.		
	80		Six closely spaced fractures, 15-70°, at 74.2'.		Brecciated zone, 90.7 - 91.4', with chloritization.
			Semi-parallel fractures, 15-45°, between 80.4' and 83.3'.		
	90		Fault zone between 85.2' and 88.8' near-vertical fracture, 85.5-86.3' semi-smooth surface with iron stains.		Trace of sandy gouge on vertical fracture, 86.8 - 88.0'.
926.4	94.4'				94.4'
			BOTTOM OF HOLE		3 BOXES OF CORE
	100				Hole not grouted.

NPA Form 7(Test) APR 66 — PROJECT CRATER LAKE/SNETTISHAM — HOLE NO. DH-130

SUMMARY LOG — HOLE NO. DH-131

N	93 406
E	86 155
SHEET	1 OF 1
SURFACE ELEV.	1020.8'
PROJECT	SNETTISHAM/CRATER LAKE
DRILL DATES: START	11 Oct 84
COMP.	13 Oct 84
DEPTH OF HOLE	221.9'
DEPTH OF OVERBURDEN	WATER 193.3' 13.1'
DIAM. OF HOLE	NQ
ROCK DRILLED	16.6'
CORE RECOVERED	7.6' OB 15.6' RK
% RECOVERY	58% OB 94% RK
ANGLE FROM VERT.	0°
AZIMUTH FROM NORTH	
COMPILED BY, DATE	Jat 20 Nov '84
DISTANCES: VERTICAL	0.0'
HORIZONTAL	0.0'

ELEV	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1020.8	0.0'		CRATER LAKE SURFACE		Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 11 Oct 84.
			WATER		HW Casing stiffener to El. 828.4 NW Casing to El. 826.7
	190				
827.5	193.3		BOTTOM OF LAKE		193.3'
			OVERBURDEN: Rock flour, soft, from 193.3' to 196.4' Boulder, 4.5' (196.9' to 201.4') Till, cobbley, gravelly, very dense, olive-Gray silt over sand to 206.4'		Started NQ coring @ 196.4'
	200				50-100% DWR
814.4	206.4		TOP OF ROCK		206.4'
	210		DIORITE GNEISS: Gray, Hard, lightly weathered, lightly fractured.		RQD 92
			Parallel low angle fractures at 208.4'.		
	220		Fractures, 25-40°, between 226.5' and 228.6'.		Left 0.4' of core in hole.
797.8	223.0		Partly healed fracture zone at 222' with rock flour on fractures.		223.0'
			BOTTOM OF HOLE		3 BOXES OF CORE
					No pressure tests.
					Till sample recovered; very dense olive-gray silt over sand. Sand washed up into NW CSG to elev. 838+
					Hole not grouted.

NPA Form 7(Test) APR 66 — PROJECT SNETTISHAM/CRATER LAKE — HOLE NO. DH-131

SUMMARY LOG

HOLE NO. DH-132

N 93,465	E 86,142	SHEET 1 OF 1
		SURFACE ELEV. 1020.0
PROJECT SNETTISHAM/CRATER LAKE	DRILL DATES: START 14 Oct 84	COMP. 16 Oct 84
DEPTH OF HOLE 243.8'	DEPTH OF OVERBURDEN WATER 203.8' 17.0'	DIAM. OF HOLE NQ
ROCK DRILLED 23.0'	CORE RECOVERED 12.2' OB 22.2' RK	% RECOVERY 96.5%
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, 0.0'	HORIZONTAL, 0.0'	Williamson 24 Oct 84

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	REMARKS
1020	0.0'	CRATER LAKE SURFACE WATER	Hole drilled from barge on lake. Water depth and lake surface elevations vary. Surface elevation given as of 14 Oct 84. HW Casing to El. 827.6
	200		
816.2	203.8	BOTTOM OF LAKE OVERBURDEN: Boulders, cobbles and gravel, quartz diorite gneiss lithology, gray, slight weathering. Boulders, 209.0' to 210.7', 210.9' to 212.5', 212.5' to 214.6', 214.6' to 216.8', 217.5' to 219.9'	Start NQ Coring at 203.8' NW CSG to El. 810.4
	210		
799.2	220.8	TOP OF ROCK QUARTZ DIORITE GNEISS, gray, hard, slightly weathered and jointed. Fractures at 0.1' to 0.6' spacing, 0-60°, between 221 and 223.5'. Calcite-filled fracture at 227.8'. Biotite zone at 229.4'. Solid core, 237.4' to 243.8'. .	220.8' RQD 93
	230		
	240		
776.2	243.8	BOTTOM OF HOLE	243.8' 4 BOXES OF CORE No pressure tests. Hole grouted.

NPA Form 7(Test) APR. 66 — PROJECT SNETTISHAM/CRATER LAKE — HOLE NO. DH-132

SUMMARY LOG

HOLE NO. DH-133

N 92,845	E 86,364	SHEET 1 OF 3
		SURFACE ELEV. 1035
PROJECT Snettisham/Crater Lake	DRILL DATES: START 21 Oct 84	COMP. 30 Oct 84
DEPTH OF HOLE 201.3	DEPTH OF OVERBURDEN 1.2'	DIAM. OF HOLE NQ
ROCK DRILLED 201.3	CORE RECOVERED 200.0	% RECOVERY 99.4
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 215°	COMPILED BY, DATE
DISTANCES: VERTICAL, 174.3	HORIZONTAL, 100.7'	[signature] 30 Oct 84

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	REMARKS
1035.0	0.0	TOP OF ROCK QUARTZ DIORITE GNEISS: gray, hard lightly weathered, lightly fractured; occasional iron staining on joints, occ. mafic zones and slicks. Joints generally have rough surfaces. Occ. asperities to 2 cm.	1.2' Muskeg removed before drilling; collared hole at top of rock.
	10		Water table @ 17.4' 30 Oct 84
	20		Lost DWR at 7'
	30	Minor chloritization 35.2-35.4'	Hole appears to be in a competent healed breccia. RQD 97-100; 0.0'-51.4'
	40		Hole located by tape and brunton survey from USGS Monument 20o, 1951.
	50	Slicks at 49.0' and 49.1' Moderately fractured 51.9'-57.6'; gray mud coating (rock flour) at 52.0', 53.5' and 57.6'	No natural fractures 19.1'-30.3' & 60.0'-68.0' RQD 89; 51.4'-57.7' RQD 100' 57.7'-76.5'
	60		0% DWR 7-180'; drill water seeping out rebound joints 10' below collar to the east and 15' below collar to the west.
	70		
	80	Acidic 84.3' to 87.7'	RQD 86; 76.5-81.4' RQD 98' 81.4'-91.4' RQD 61; 91.4'-101.1'
	90	5 mm gray mud w/coarse sand on joint at 90.9' Acidic 94.0' to 97.2'	Spiral" fractures 97.5'-100.9' 108.3'-110.9' and 150.2'-150.3' Maybe drilling problem.
948.4	100		

NPA Form 7(Test) APR. 66 — PROJECT Snettisham/Crater Lake — HOLE NO. DH-133

SUMMARY LOG

HOLE NO. DH-133	N 92,845 / E 86,364	SHEET 2 OF 3 / SURFACE ELEV. 1035	
PROJECT Snettisham/Crater Lake	DRILL DATES: START 21 Oct 84	COMP. 30 Oct	
DEPTH OF HOLE 201.3'	DEPTH OF OVERBURDEN 1.2'	DIAM. OF HOLE NO	
ROCK DRILLED 201.3'	CORE RECOVERED 200.0'	% RECOVERY 99.4'	
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 215°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 174.3' ; HORIZONTAL, 100.7'		[signature] 20 Nov 84	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
948.4	100		QUARTZ DIORITE GNEISS; con't. gray mud on joint @ 103.8'		RQD 75', 101.1' - 111.3'
	110				No natural fractures, 110.9'-120.4' and 132.9'-145.9'
	120		Quartz diorite, medium grained w/ equidimensional hornblende XLS; no foliation; gradational borders; 118.9' to 122.9'		
			60° joint w/2 cm asperities and gray mud (rock flour) on joint at 126.9'		
	130				RQD 91 - 100' 111.3' -201.3'
	140		Acidic 144.3'- 147.5'		
	150		Acidic 154.7-155.7'		
			Artesian flow 158.5'-158.75' Broken zone, 158.5'-158.75'		Flow rate 0.23 ft 3/min at elev. 1039.5'
	160		Highly fractured 162.1-162.7' generally soft with high mica content 162.2' - 162.6'		
	170				
	180				
	190				
861.8	200				

NPA Form 7(Test) PROJECT Snettisham/Crater Lake HOLE NO. DH-133

SUMMARY LOG

HOLE NO. DH-133	N 92,845 / E 86,364	SHEET 3 OF / SURFACE ELEV. 1035	
PROJECT Snettisham/Crater Lake	DRILL DATES: START 21 Oct 84	COMP. 30 Oct 84	
DEPTH OF HOLE 201.3'	DEPTH OF OVERBURDEN 1.2'	DIAM. OF HOLE NO	
ROCK DRILLED 201.3'	CORE RECOVERED 200.0	% RECOVERY 99.4	
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 215°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 174.3 ; HORIZONTAL, 100.7		[signature] 20 Nov 84	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
860.7	201.3		QUARTZ DIORITE GNEISS, Con't.		
			Bottom of Hole		Left 0.2' in hole 22 boxes of core

NPA Form 7(Test) PROJECT HOLE NO. DH-133

SUMMARY LOG — HOLE NO. DH-134

N 92,848	E 86,356	SHEET 1 OF 2 — SURFACE ELEV. 1037.2
PROJECT Snettisham/Crater Lake	DRILL DATES: START 5 Nov 84	COMP. 8 Nov 84
DEPTH OF HOLE 133.5'	DEPTH OF OVERBURDEN 0.4'	DIAM. OF HOLE NQ
ROCK DRILLED 133.5'	CORE RECOVERED 132.6'	% RECOVERY 99.3
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 302°	COMPILED BY, DATE: Jat 20 Nov 84
DISTANCES: VERTICAL, 115.6'; HORIZONTAL, 66.8'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1037.2	0.0	QUARTZ DIORITE GNEISS; Gray, hard, lightly weathered, lightly fractured; iron staining on joints common above 13'. Occasional slickensides; occ. asperities to 15mm.		0.4' Muskeg removed before drilling; collared hole at top of rock.
	10	Slicks at 12.1' and 13.3'		DWR 50% - 100%; 0.0' - 24.6 gray - green to milky whit
		Acidic 6.7 - 9.3'		Water table 14.3' 9 Nov 84
	20			Open joints at 11.0' & 11.2 Interconnected with DH-133.
		Shear at 22.9'; surface moderately to highly weathered with sand.		RQD 93 - 100; 0.0' - 33.5'
		Slicks at 26.9'		RQD 88; 33.5 - 43.5' Lost DWR at 24.5' Lost DWR at 34'
	30			Drill water seeping out in Crater Creek, 20' U/S of outlet ridge
		Shear 33.9' to 37.1', very minor. 0.05', lithified gouge w/slicks at 37.1'. Shear appears to have been activated several times.		
	40	Acidic 38.8' to 43.0'		No natural fractures 37.1' - 72.0'
	50			RQD 99-100; 43.5' - 93.5' Minor DWR 26' - 34' 0% DWR 34' - 48' 25% DWR 48' - 55' Entire hole appears to be a competent healed breccia
	60			
	70	Joint with gray mud at 73.2'		10% - 50% DWR; 74' - BOH
	80	Slicks at 84.1'		No natural fractures 84.1' - 99.6'
	90			RQD 89; 93.5' - 103.5'
950.6	100			

NPA Form 7(Test) APR. 66 — PROJECT Snettisham/Crater Lake — HOLE NO. DH-134

SUMMARY LOG — HOLE NO. DH-134

N 92,848	E 86,356	SHEET 2 OF 2 — SURFACE ELEV. 1037.2
PROJECT Snettisham/Crater Lake	DRILL DATES: START 5 Nov 84	COMP. 8 Nov 84
DEPTH OF HOLE 133.5	DEPTH OF OVERBURDEN 0.4'	DIAM. OF HOLE NQ
ROCK DRILLED 133.5'	CORE RECOVERED 132.6'	% RECOVERY 99.3
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 302°	COMPILED BY, DATE: Jat 20 Nov 84
DISTANCES: VERTICAL, 115.6'; HORIZONTAL, 66.8'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
950.6	100	QUARTZ DIORITE GNEISS; cont		RQD 86' 103.5'-105.6' RQD Ø' 105.6'-107.9'
		Slicks @ 104.7' & 105.4' Shear 103.6' - 107.9' highly weathered. Very highly fractured. Hard gouge at 107.9'		"CLIFFSIDE SHEAR"
	110	Slicks @ 109.9'		
		Slicks at 114.7' Minor alteration to 118.1'		RQD 89-96; 107.9' - BOH
	120	1 cm thick maroon mineralization, 120.5' & 121.0'		
		Slicks 122.5'		
		Slicks 125.4 & 126.2' Slicks with very minor alteration 127.4		
	130	Slicks 127.6', 128.0' & 129.3'		
921.6	133.5	BOTTOM OF HOLE		0.3' left in hole 14 boxes of core
	140			
	150			

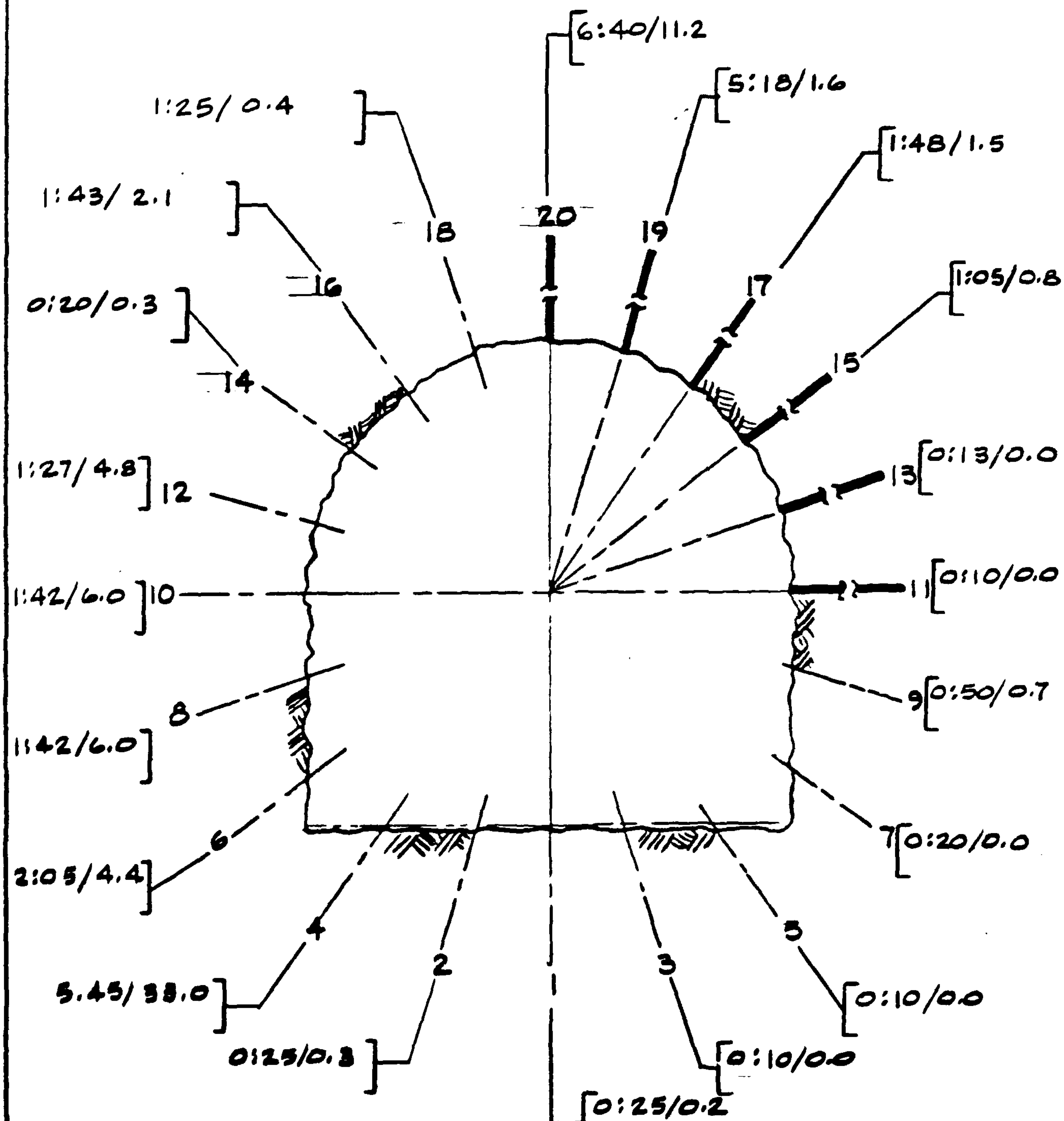
PRESSURE TESTS

Depth (Ft)	K (Ft./min)
28.2' - 100.9'	Avg 0.18 x 10^{-5}
98.2' - 110.9'	0.075 x 10^{-5}
111.8'-133.5'	0.0

NPA Form 7(Test) APR. 66 — PROJECT Snettisham/Crater Lake — HOLE NO. DH-134

APPENDIX G

GROUT CURTAIN SUMMARIES

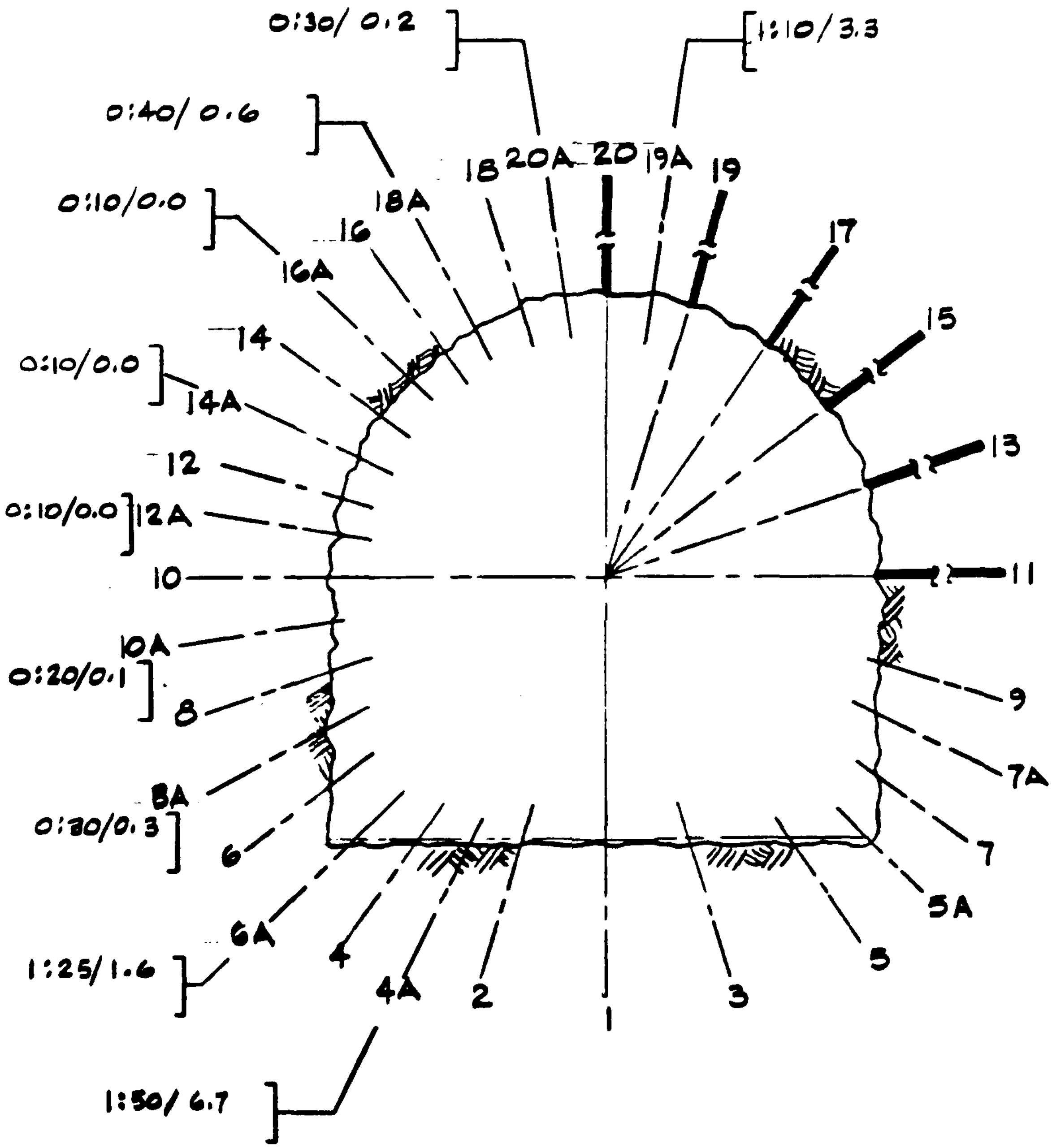


NOTES:
1. EXPLANATION OF HOLE SUMMARY 0:20/0.0 — TIME IN HOURS: MINS. — QUANTITY IN CU. FT. (GROUT)

GROUT CURTAIN SUMMARY – STA. 67+25

LACHEL & ASSOCIATES

FIGURE G-1



NOTES:

1. EXPLANATION OF HOLE SUMMARY 0:20/0.0

TIME IN HOURS: MINS.

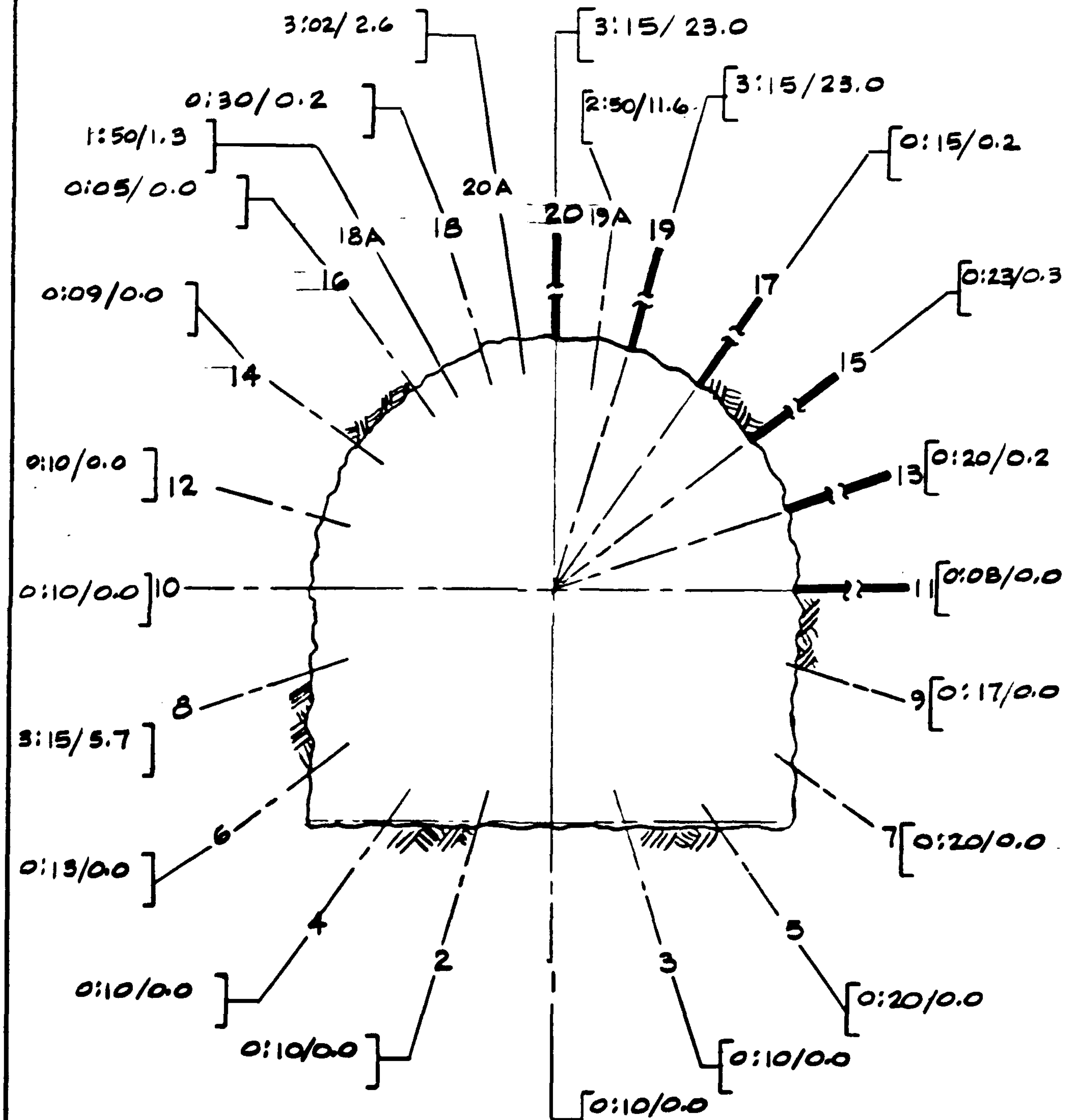
QUANTITY IN CU. FT. (GROUT)

LACHEL & ASSOCIATES

GROUT CURTAIN SUMMARY – STA. 67+30

SUPPLEMENTARY GROUTING TO STA. 67+25

FIGURE G-2

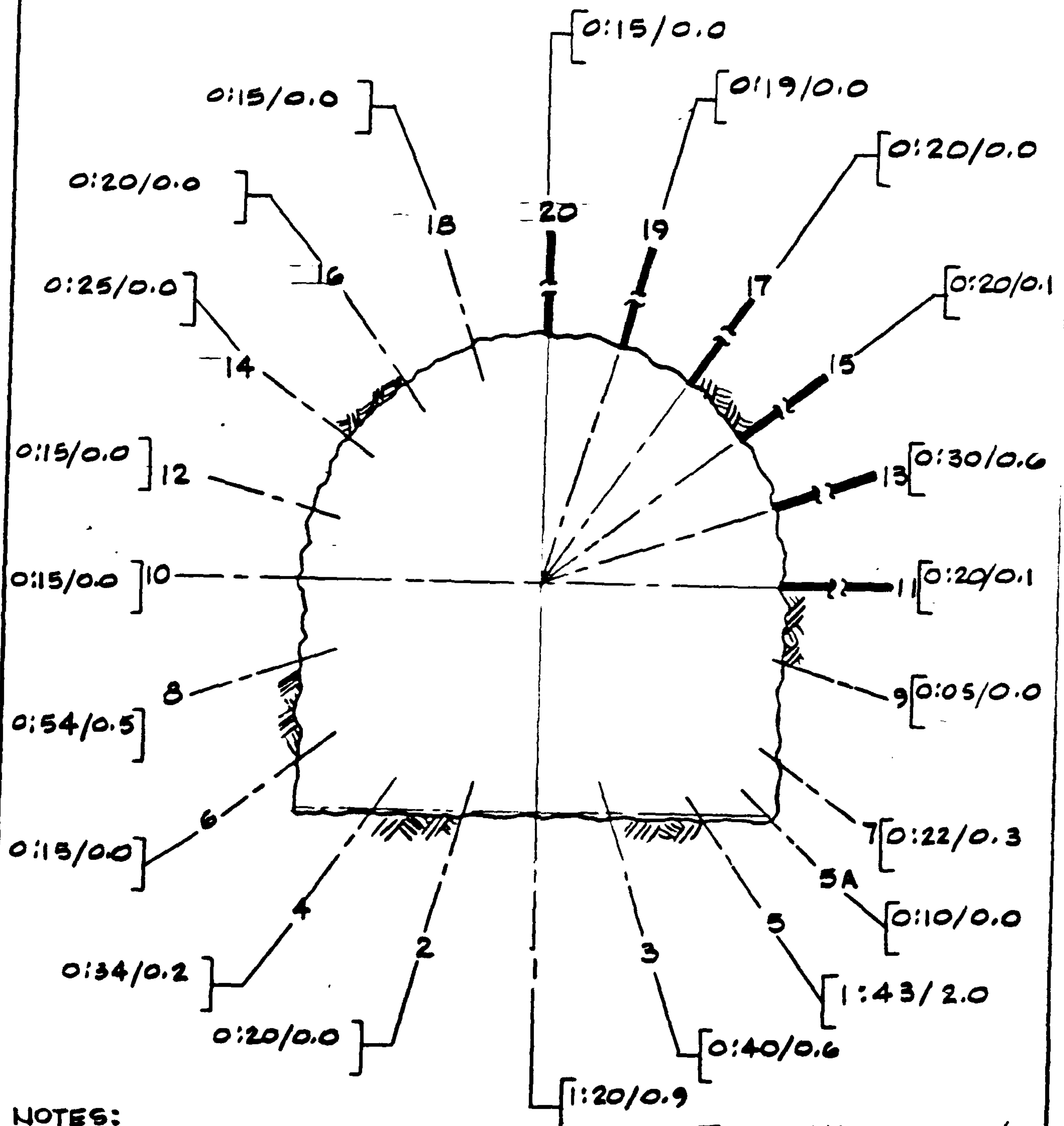


NOTES
1. EXPLANATION OF HOLE SUMMARY 0:20/0.0 TIME IN HOURS : MIN'S QUANTITY IN CU. FT(GROUT)

GROUT CURTAIN SUMMARY – STA. 67+55

LACHEL & ASSOCIATES

FIGURE G-3



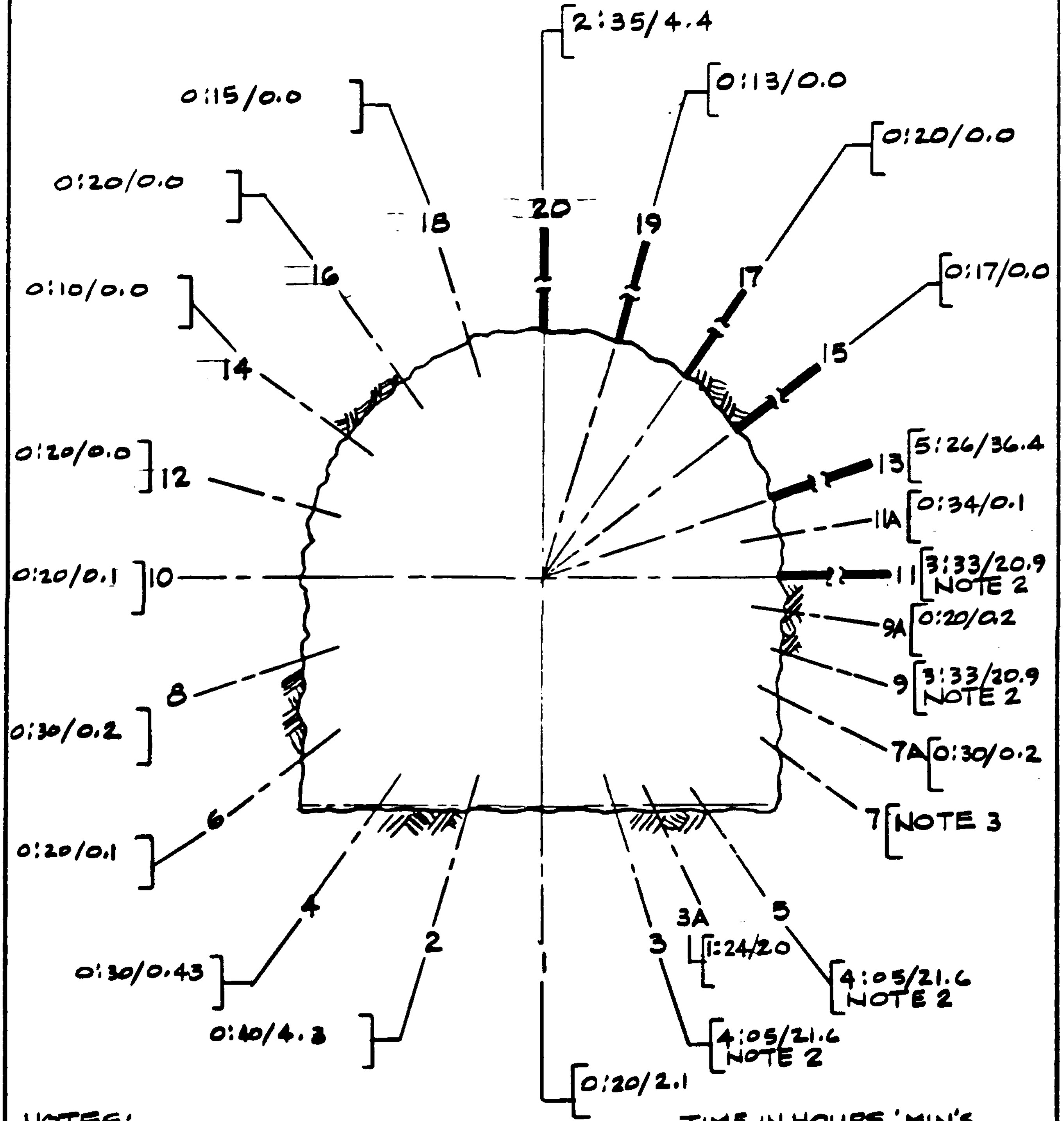
NOTES:

1. EXPLANATION OF HOLE SUMMARY 0:20/0.0 — TIME IN HOURS : MIN'S. — QUANTITY IN CU. FT. (GROUT)

GROUT CURTAIN SUMMARY – STA. 67+70

LACHEL & ASSOCIATES

FIGURE G-4



NOTES;

TIME IN HOURS: MIN'S

1. EXPLANATION OF HOLE SUMMARY 0:20/0.0

2. HOLES 9 & 11, 3 & 5 WERE PUMPED SIMULTANEOUS.

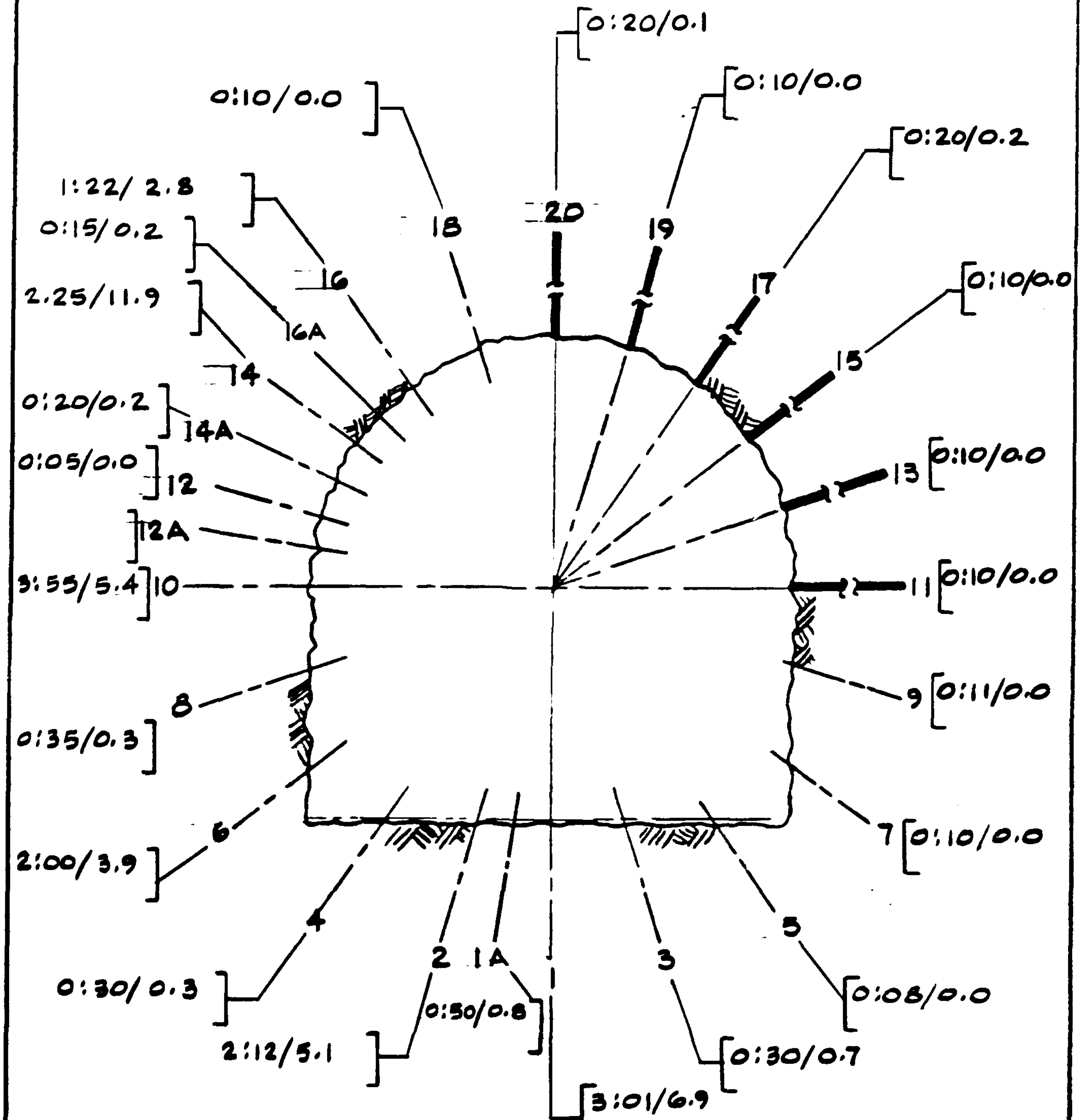
QUANTITY IN CU. FT. (GROUT)

3. HOLE 7A PUMPED IN LIEU OF 7.

GROUT CURTAIN SUMMARY – STA. 67+85

LACHEL & ASSOCIATES

FIGURE G-5



NOTES:

1. EXPLANATION OF HOLE SUMMARY 0:20/0.0

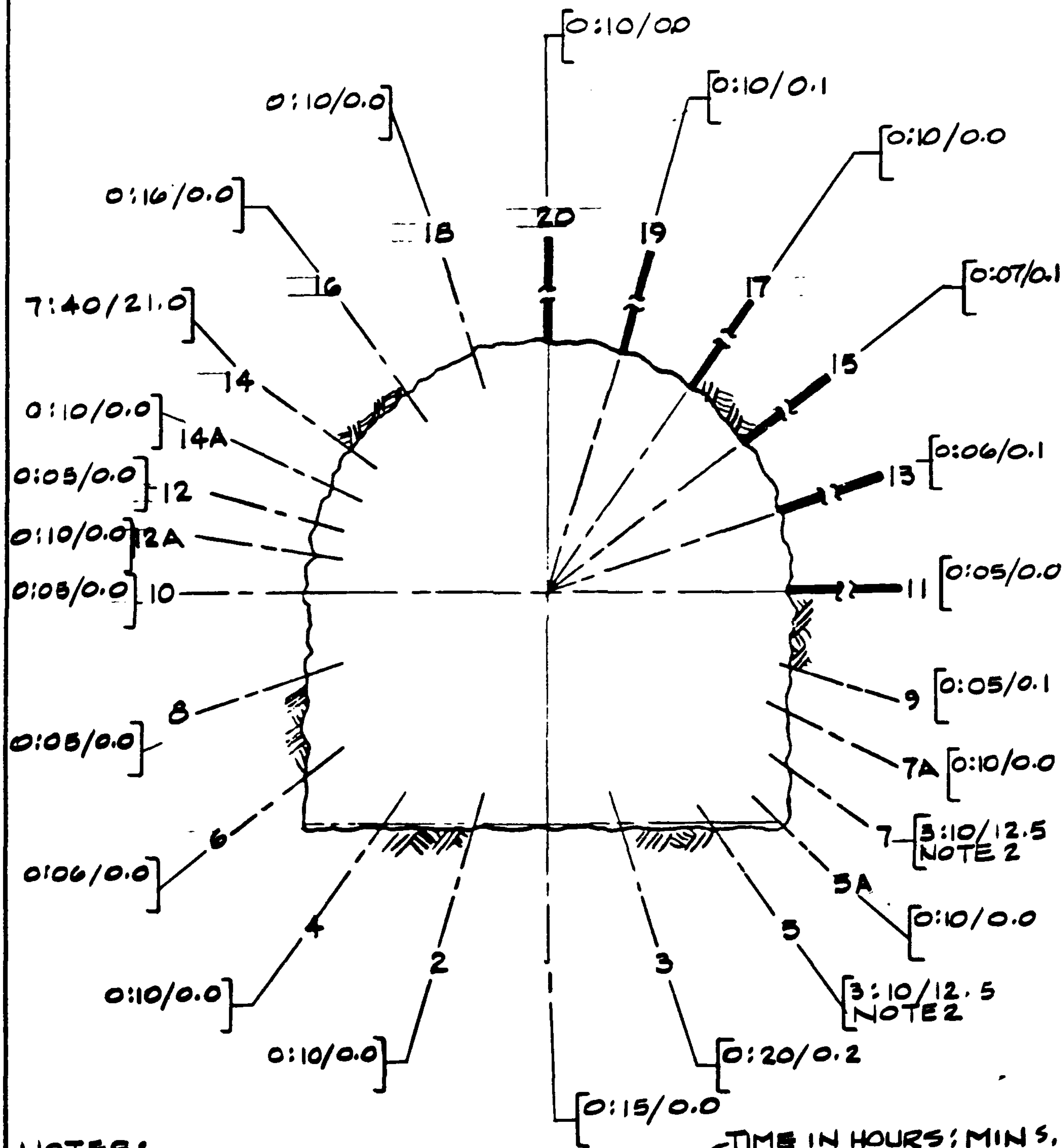
TIME IN HOURS: MIN'S

QUANTITY IN CU. FT. (GROUT)

GROUT CURTAIN SUMMARY — STA. 68+10

LACHEL & ASSOCIATES

FIGURE G-6

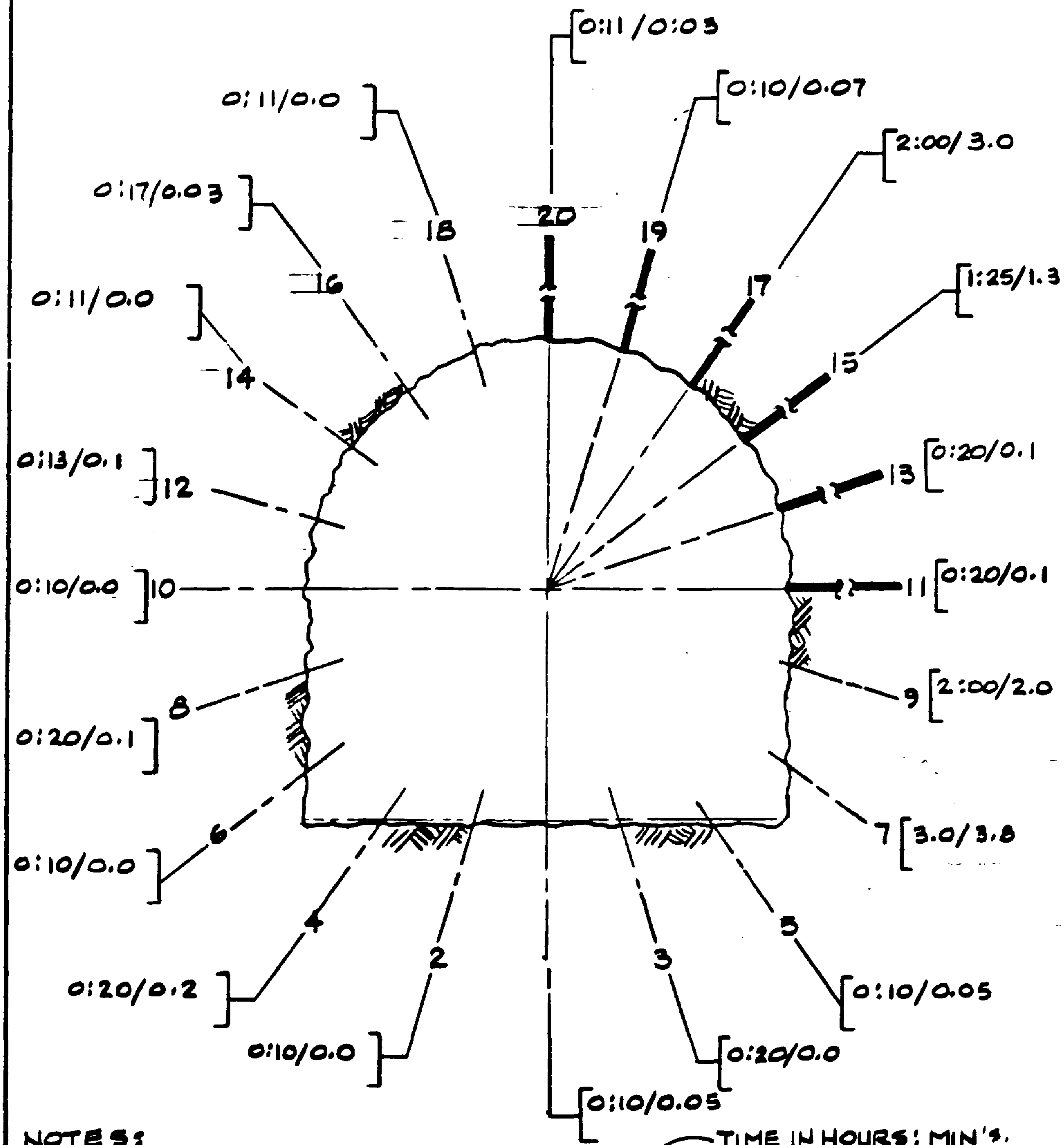


NOTES:
1. EXPLANATION OF HOLE SUMMAY [0:20/0.0 — TIME IN HOURS: MINS.; QUANTITY IN CU. FT. (GROUT)
2. HOLES 5 & 7 WERE PUMPED SIMULTANEOUS

GROUT CURTAIN SUMMARY — STA. 68+80

LACHEL & ASSOCIATES

FIGURE G-7



NOTES:
1. EXPLANATION OF HOLE SUMMARY 0:20/0.0 — TIME IN HOURS: MIN'S. / QUANTITY IN CU. FT. (GROUT)

GROUT CURTAIN SUMMARY – STA. 69+18

LACHEL & ASSOCIATES

FIGURE G-8

APPENDIX H

ROCK TEST RESULTS

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
NPAEN-FM-M	Crater Lake, Rock Core Test Results

TO	FROM	DATE	CMT 1
NPAEN-FM-G	NPAEN-FM-M	31 May 84 Pekar/jah/2-4435	

1. Attached are the test results for the Crater Lake rock core samples.

2. This completes all work under this request.

James W. Pekar

JAMES W. PEKAR
Acting Chief, Materials & Instrumentation
Section

1 Incl
as

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION MATERIALS LABORATORY
CORPS OF ENGINEERS
RT. 2. BOX 12A
TROUTDALE, OREGON 97060

ATTN: NPAEN-FM-M 25 May 1984

W.O. 84-SC-576

Subject: Report of Tests on Rock Cores

Project: CRATER LAKE
Intended Use: -
Source of Material: Crater Lake, Alaska

Submitted by: NPAEN-FM-M
Date Sampled: Date Received: 16 Apr 84
Method of Test or Specification: ASTM, CRD, RTH

Reference: a. DA Form 2544 Order No. E86840029 dated 16 Apr 84.
b. Letter from the Robbins Co. dated Jan 19, 1981, subject "Bradley Lake Hydropower Project" which included rock test data page to be used as data format.
c. Telecons with Del Thomas, Jim Pekar, and Pat Galbraith (NPAEN-FM) on 12, 16, and 27 Apr, and 1 and 3 May 84; wherein, test details were discussed, and results were reported.

1. Attached, confirming telecon data, are:

a. Incl 1, one REPORT OF DYNAMIC TESTS ON NQ ROCK CORES, summary sheet.

b. Incl 2, one REPORT OF DIRECT SHEAR TESTS ON INTACT NQ ROCK CORES, summary sheet.

c. Incl 3, one graph, TRIAXIAL COMPRESSION TEST ON ROCK CORE.

d. Incl 4, one REPORT OF TESTS ON NQ ROCK CORES, summary sheet.

2. Due to insufficient sample lengths, all requested tests could not be performed. For sample DH-106 (260.1-260.7 ft) a single triaxial compression tests was substituded for the three direct shear, one unconfined compression, and impact tests that were requested. Dynamic tests could not be accurately performed on samples DH-106 (260.1-260.7 ft) and DH-106 (366.3-367.5 ft) due to the short sample lengths.

3. This completes all work requested.

Incl (dupe)
as

JAMES PAXTON,
Director

Copy Furnished:

NPDEN-GS&M

MAY 25 1984

NPDEN-GS-L (84-SCH-576)

CRATER LAKE

Report of Dynamic Tests on NQ Rock Cores 1/

Sample No.	Depth, ft	Dynamic Modulus of Elasticity, $E_{dyn} \times 10^6$ psi	Velocity, ft/sec
DH-106	260.1-260.7	2/	2/
DH-106	366.3-367.5	2/	2/
DH-111	628.7-630.1	4.3	7,100
DH-115	644.8-646.8	5.7	7,900

Long. vel.

NOTE: 1/ Tests performed in accordance with CRD-C151, RTH-110, ASTM-2845.

2/ Core lengths too short to accurately perform test.

Received: 16 Apr 84

MAY 25 1984

NPDEN-GS-L (84-SCH-576)

CRATER LAKE

Report of Direct Shear Tests on Intact NQ Rock Cores 1/

@max shear stress

Disp.	Sample	Depth, ft	Normal Stress, psi	Maximum Shear Stress, psi	dia	L
0.009"	DH-106	366.3-367.5	400	2870	1.86"	.1
0.010"	DH-106	366.3-367.5	800	2690 2/	1.86"	.9
0.018"	DH-106	366.3-367.5	1500	5000 3/	1.86"	3.[illegible]
0.014"	DH-111	628.7-630.1	400	1790	1.86"	[illegible]
0.013"	DH-111	619.2-620.3 4/	800	2070	1.86"	[illegible]
0.016"	DH-111	628.7-630.1	1500	2610	1.86"	2.9
0.007"	DH-115	644.8-646.8	400	2080	1.87"	[illegible]
0.011"	DH-115	644.8-646.8	800	1510 2/	1.87"	3.1
0.013"	DH-115	644.8-646.8	1500	2650	1.87"	1

NOTE: 1/ Tests performed in accordance with RTH-203-80.

2/ Sample failed along tight, healed fracture.

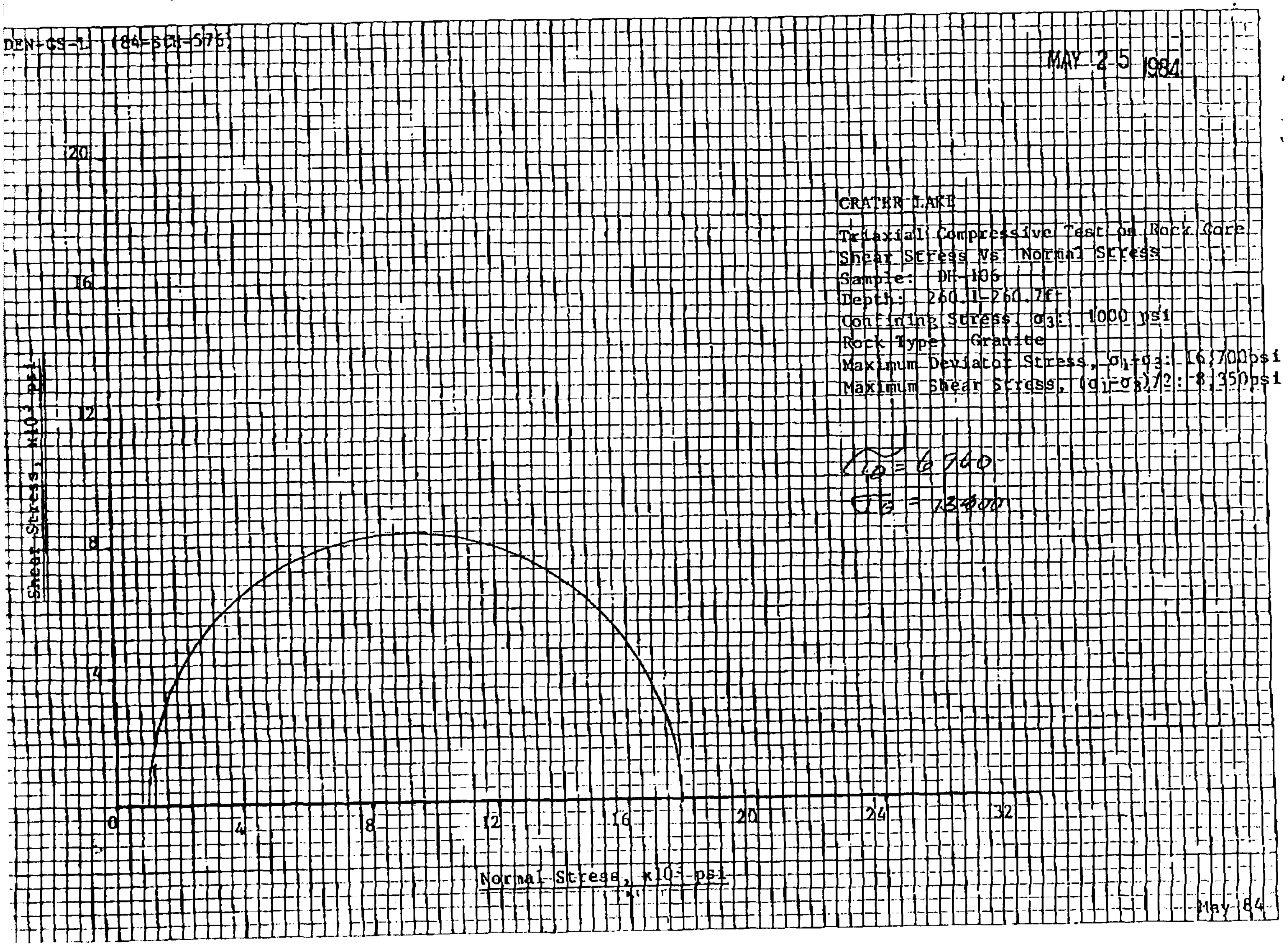
3/ Sample failed along granite/diabase interface at elevation 366.5 ft.

4/ Insufficient sample from 628.7-630.1 ft for requested tests, core from 619.2-620.3 ft substituted.

Received: 16 Apr 84

K•E 5 X 5 TO 1/2 INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0860



MAY 25 1984

NPDEN-GS-L (84-SC-576)

CRATER LAKE

Report of Tests on NQ Rock Cores

Sample	Depth, ft	Description	Impact Test, ft-lbs 1/	Unconfined Compressive Strength, psi	Bedding Orientation	SiO_2 Content, %	HCL Reaction 2/	Moh's Hardness Range	Wet Density, pcf	Moisture Content %
DH-106	260.1-260.7	Granite, weathered with calcite veins, approx. 10% biotite.	3/	3/	massive, veins at 55-66°.	30-40	3-weak due to weathered nature of specimen or calcic plagioclase.	6-7	164.7	1.5
DH-106	366.3-367.5	Diabase, fresh finegrained with calcite veins.	4 2 4/	17,110	massive, veins at 45-65°.	5-10	2-spots and veins.	6-7	173.5	0.9
DH-111	628.7-630.1	Granite, fresh, approx. 10% biotite, ½ plagioclase feldspar, ½ potassium feldspar.	9 11 9	32,730 31,500	massive, possible cooling bands of biotite at 30-40°.	30-40	2-spots and end surfaces.	6-7	163.0	0.2
DH-115	644.8-646.8	Hornblende granodiorite, fresh, pyrite, chloritization, approx. 40% hornblende and biotite.	5 7 4/	19,540	massive, possible brecciated or metamorphosed texture.	20-30	2-spots.	5-7	182.9	0.4

NOTE: 1/ Impact test performed according to ASTM D3-61 procedure.

2/ HCL reaction: 1-none 2-spots or seams only 3-week 4-strong.

3/ Insufficient sample to perform tests.

4/ Insufficient sample for three tests.

Received: 16 Apr 84.

Rock Sample Identification Sheet

DATE OF RECEIVAL: May, 1984

ROBBINS IDENTIFICATION NO. 1882

LOCATION OR SOURCE OF ROCK: Crater Lake, Alaska

COMPANY SUBMITTING ROCK:

PROJECT: Hydroelectric

ROCK PETROLOGY: Quartz diorite gneiss, Basalt (?)

TYPE OF BORE: ☒ TUNNEL ☐ RAISE

BORE DIAMETER:

BORE LENGTH:

REQUESTED INFORMATION:

- ☒ COMPRESSIVE STRENGTH
- ☒ INDENTATION TEST
- ☒ POINT LOAD TEST
- ☒ QUARTZ CONTENT (ABRASIVENESS)
- ☐ CUTTER PENETRATION RATE
- ☐ OTHER

OTHER COMMENTS:

The Robbins Company
Rock Sample Test Data

ROCK REPORT # 1882

RMI # R-20-20

FOR: Crater Lake, Alaska

DATE: 5/21/84 BY: GD

RMI SAMPLE NUMBER	CUSTOMER IDENTIFICATION and DESCRIPTION	COMPRESSIVE STRENGTH (PSI)	BEDDING ORIENT. TO AXIS	POINT LOAD TEST INDEX**	BEDDING ORIENT. TO AXIS	QUARTZ CONTENT (hand-lens)	HC 1 * REACTION	MOHS' HARDNESS RANGE	DENSITY (g/cm³)
4720	"DH 106, 260.3-260.7" Quartz diorite gneiss[M]. Fractured and weathered.	X	X	5.0 5.0 5.0	X	10-20%	1	3-7	X
4721	"DH 106, 365.3-365.8-Basalt" Fine grained dark grey rock-andesite or basalt.	28400 (1-test)	X	5.7	X	< 10%	1	3-7	2.842
4722	"DH 106, 253.6-254.0-Basalt" Same as 4721.	30865 (1-test)	X	X	X	< 10%	1	3-7	2.693
4723	"DH 115", 643.8-644.75-Quartz diorite gneiss", Fresh, coarse-grained.	9020 12218 10620	X	6.3 5.7 6.0	X	10-20%	1	3-7	2.868
4724	"DH 111, 620.3-621.2- Quartz diorite gneiss". Fresh; divided into feldspar-rich and biotite-rich zones.	15495 15495 14495	Fd-rich		X	15-25%	1	3-7	2.63 and 2.75
		9020 8376 8698	Biot-rich	5.7	X				
4725	"DH 111, 626.7-628.7-Quartz diorite gneiss". Same as 4724.	16786	Fd-rich	5.7	X	15-25%	1	3-7	2.64 and 2.74
		15464	Biot-rich	5.0 5.4					

* HCl REACTION: 1. None; 2. Spots or Seams; 3. Weak (dolomitic); 4. Strong (limestone) ** Standardized to 50 mm diameter

POINT LOAD INDEX [illegible] Weak, [illegible] Weak, [illegible] medium,

TELEPHONE OR VERBAL CONVERSATION RECORD For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.		DATE 15 June 1984
SUBJECT OF CONVERSATION Rock Test Report - Crater Lake Tunnel		
INCOMING CALL		
PERSON CALLING	ADDRESS	PHONE NUMBER AND EXTENSION
PERSON CALLED	OFFICE	PHONE NUMBER AND EXTENSION
OUTGOING CALL		
PERSON CALLING Pat Galbraith	OFFICE NPAEN-FM-G	PHONE NUMBER AND EXTENSION 2-2718
PERSON CALLED Tim Siemens	ADDRESS Troutdale Lab (NPD)	PHONE NUMBER AND EXTENSION 503-665-4166

SUMMARY OF CONVERSATION

The following clarifications are needed:

1. CRD-C-151 cited; This standard has been withdrawn. Tim says 151; RTH-110 & ASTM D-2845 are all essentially the same. OK. Recommended he not cite C-151 anymore.

2. Need V_s & V_p to complete dynamic moduli for ASTM D-2845.

3. Need σ_θ & σ_θ to complete tri-axe info. A multi-stage was not possible. ϕ envelope cannot be constructed w/o more samples.

Tim to call back.

Pat Galbraith.

P.S. Simple shear variations ~~due~~ due to breakage on or thru XLs - usually feldspars. Logical for high grade metamorphic.

Pat.

ASTM D-3 Drylock test test discontinued ??

DA FORM 1 APR 66 751 REPLACES EDITION OF 1 FEB 58 WHICH WILL BE USED.

TELEPHONE OR VERBAL CONVERSATION RECORD

For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.

DATE: 25 June 1984

SUBJECT OF CONVERSATION: Rock Test Report - Crater Lake Tunnel.

INCOMING CALL

PERSON CALLING	ADDRESS	PHONE NUMBER AND EXTENSION

PERSON CALLED	OFFICE	PHONE NUMBER AND EXTENSION

OUTGOING CALL

PERSON CALLING	OFFICE	PHONE NUMBER AND EXTENSION
Pat Galbraith	NPAEN-FM-G.	2-2718.

PERSON CALLED	ADDRESS	PHONE NUMBER AND EXTENSION
Tim Siemens	Troutdale Lab (NPD)	503-665-4166

SUMMARY OF CONVERSATION

1. Returned Tim's call re: 15 June Telecon
2. $\sigma_\theta = 6760 psi$, $\sigma_\theta = 13800 psi$
3. V_s & V_p not measured.
4. ASTM-D3 used - NPA does not have a copy.
5. Dimensions as follows:

	σ	Disp (@max shear stress)	Dia	L
DH-106	400	0.009"	1.86"	3.1"
	800	0.010"	1.86"	2.9"
	1500	0.019"	1.86"	3.0"
DH-111	400	0.014"	1.86"	2.6"
	800	0.013"	1.86"	2.5"
	1500	0.016"	1.86"	2.9"
DH-115	400	0.007"	1.87"	3.2"
	800	0.011"	1.87"	3.1"
	1500	0.013"	1.97"	3.1"

Pat Galbraith

DA FORM 1 APR 66 751 REPLACES EDITION OF 1 FEB 58 WHICH WILL BE USED.

APPENDIX I

CONSULTANTS REPORTS

BRAWNER REPORT

C. O. BRAWNER ENGINEERING LTD.
Consulting Geotechnical Engineers

Ste. 502, Kapilano 100, 100 Park Royal
WEST VANCOUVER, B.C., CANADA V7V 3N6

Telephone: (604) 922-3717
(604) 926-2747
Telex: 04-352846

REPORT

TO

LCMF Limited

re

Contractors Claim

Snettisham Stage 2 Crater Lake Development

June, 1987

Enclosure 2

TABLE OF CONTENTS

1.0 Introduction

C.O. Brawner, P. Eng. was retained by LCMF Ltd., to review site conditions, reports, documents, plans and specifications to determine if the conditions encountered during construction differ significantly from what is presented by the contract plans and specifications.

Two specific locations are involved - (a) where the Hilltop shear intersects the tunnel and (b) at the Lake tap.

The Contractor, Pacific Ventures Inc., has submitted letters advising changes in the materials, conditions or work have occurred and indicated they involve additional time and cost.

Relevant letters are included as Appendix A. Changes claimed are as follows.

- Change in site conditions within the tunnel and vicinity of the lake tap plug.

- Directions to change drill core hole location and locate pilot holes and core holes at locations other than shown on contract drawings.

- Change in tunnel alignment near the lake tap.

- To perform underground grouting with different procedures and materials than the contract called for.

The author visited the site on May 15. The project program reports, specificiations, plans, photographs, etc were reviewed with Mr. Bill Creger and Captain Doug Kennedy. The tunnel was inspected underground in the afternoon. Representative photos were taken (Appendix B).

Considerable information was provided; this included:

- Site Plan -FM-1-Sheet 192
- Geology plan -FM-2-Sheet 193
- Geology sections -FM-3-Sheet 194
- Contract specifications

- Crater Lake phase 1 Foundation report - 1986
- Abstract of construction offers
- Notes by W.L. Sanguine re Hilltop shear core drilling.
- Notes by Grissly Construction re Hilltop shear core drilling
- Correspondence on differing site conditions
- Plan of Hilltop shear zone intercept
- Plan of shear-tunnel intersection
- Post blast reports by Grissly Construction
- Profile of lake tap section and drill rounds
- Profile of lake tap and drill probe locations
- Grissly Construction drawing of lake tap probes
- Lake tap pilot and probe holes

2.0 Claim re the Hilltop Shear Zone

(a) Contractors Procedure Through the Hilltop Shear

Shortly after the Contractor first intersected the Hilltop shear zone he was requested by the Corps of Engineers to apply shotcrete for support. The contract calls for shotcrete and the Corps reasonably expected the Contractor to be able to meet this request. However, the necessary materials and equipment were not available for immediate use. The Contractor had a supply of steel sets on site and these were used to allow the tunnelling to proceed. When the required steel sets available at the site were used up the Contractor was instructed to change to shotcrete support. He still was not able to comply with this instruction. The Contractor was advised to shut down for the Christmas holiday and return after the holidays with shotcrete capability.

After Christmas the application of shotcrete provided the required support along the shear zone exposure at less expense and time than for steel sets.

I conclude that the Contractor did not meet the requirements of the contract by not having the capability to apply shotcrete when the shear zone was encountered. This delayed the project and has likely cost the Corps additional money. Instead of the Contractor having a claim for change of conditions, I believe the Corp - if it wishes - has reasonable basis for a counter claim on the Contractor.

(b) Discussion re Claim re Hilltop Shear Zone

the Hilltop shear zone was encountered between about station 9+93 and 9+18, a distance of about 75 feet. It intersected the tunnel at an angle of about 16 degrees (Appendix C) with a dip of about 80 degrees to the south east. Section 4.3.1 of the specifications states "the central portions of each of the shear zones are expected to be closely broken, mylonitized, and altered rock, with definite lenses or stringers of gouge. Bordering each central zone are phases of less severely broken or altered rock grading outwards to the intact mass of rock". I consider that this description accurately describes the conditions which I observed of the Hilltop shear in the tunnel.

Section 4.3.1.1 states "These (shear zones) vary from single discontinuities with less than 0.1 ft. of gouged or altered rock to an estimated 35 feet of fractured and altered rock, where the tunnel crosses the cliffside/Hillside shear zone". Section 4.3.1 states "The Crater Lake tunnel passes through most of the fractures at an acute angle of 20 to 30 degrees.

I interpret from the contract that a shear zone about 35 feet wide was expected to intersect the tunnel at 20 to 30 degrees. If this shear zone was plotted on the plan - assuming an average 25 degree intersection, the shear zone would have been intersected for a length of about 110 feet along the tunnel, substantially greater than actually occurred. In addition, the entire tunnel width would have been in the shear zone for nearly 60 feet. This would have resulted in more severe ground conditions and tunnelling problems than actually occurred.

I conclude the actual conditions were much better than would be inferred from the contract.

(c) Excess Blasting Used Through Shear Zone

The Contractor used a powder factor ranging from about 7.5 lb. per cu. yd. to 10 lb. per cu. yd. (Appendix D). Excessive seismic acceleration forces generated by blasting damage rock in the tunnel walls and results in extra support being required. This is even more critical where faulted and sheared zones exist.

10# too hi
7.5 ok
in shears
6-7

A more reasonable powder factor for the conditions through the shear zone would have been about 4 to 5 lb. per cu. yd.

This Contractor did reduce the length of round through some of the shear zone which would provide some benefit.

There was limited evidence of blast hole exposures in the tunnel wall and roof through the shear zone area.

I conclude that the Contractor used excess explosive in the tunnel in the area of the shear zone. This required more support than would have been required with a lower powder factor.

I recommend the claim re changed conditions relating to the intersection of the Tunnel with the Hilltop be rejected. Because of the Contractor's inability to provide shotcrete support when required, the need to use alternate more expensive steel support and the excess blasting I consider the Corps has grounds for a counter claim with the Hilltop shear.

3.0 Claim re Lake Tap Tunnel and Plug

(a) Contractor responsibility

The contract required the Contractor to retain a Specialist Engineer in Lake Tap engineering and construction to advise and direct the Contractor and to liase with the Specialist engineer retained by the Corps for the Lake Tap. These specialist engineers were required to meet regularly to evaluate the ongoing program and to carefully plan each stage as the tunnel approached the lake tap.

The contract emphasized the importance of the Contractor's responsibility, for example, Section 2F - Lake Tap procedures section 2 General - "Approval of the contractors plan for the lake tap will in no way relieve the Contractor of responsibility for the adequacy of any part of his plan or operations".

Under Section 2 page 2F-3 it states that "the Contractor has a special responsibility in the period from the time probe drilling commences to the time the lake plug has been reached and its confirmation established".

Section 6 - PROBE DRILLING states "The Contractor has a special responsibility as the tunnel face approaches the lake tapping area".

"The Contractor must follow the approved probe drilling procedures very carefully".

Section 9 - Lake Tap Responsibility - states "Nowithstanding any of the above, it shall be the Contractors responsibility to perform a successful lake tap, complete. The data provided is for general information and it is the Contractors responsibility to provide his plan, which is subject to the approval by the Contracting officer"..

The final stages leading up to the drilling for the plug must be developed and monitored carefully. The exact geologic conditions and lake-rock surface cannot be economically determined accurately prior to the contract. The contract required a detailed program of probe holes and logging of probe holes to locate the lake - rock contract and to determine whether adverse rock conditions and whether open joints existed in the plug area. The contract clearly indicated some adverse geologic conditions may require grouting and the alignment of the tunnel might require some relocation.

I consider the contract adequately defined the lake tap probe program and alerted the Contractor to the potential of the need for grouting and the potential of a change in tunnel alignment.

(b) <u>Presence of joints requiring grouting</u>

The Contractor has indicated the intent to claim regarding a change in grout materials and procedures, excessive water producing fissures, change in probe hole locations and tunnel alignment near the lake tap plug.

Section 2C - Excavation for Tunnels, Portals, Shafts, Rooms and Lake Tap states in 4. AREA DESCRIPTION "Excavations for the shaft collar of the single tank and portals are anticipated to encounter overburden of earth and boulders, and weathered and jointed rock".

Section 4.2.1 Low Angle Joints states - "The low angle joints are stress relief or unloading joints caused by glacial scour of the overlying rock and later removal of the ice load. ..... These joints are roughly perpendicular to the tensile stress which is usually sub parallel to the exposed rock surface.... Low angle joints commonly die out with depth. Such joints were encountered in the Long lake access adit...... These joints do exist".

Section 4.2.2 High Angle Joints states - "The other major group of joints, the high angle joints are developed by tectonic stress... In general these joints are more nearly planar and more continuous than the low angle unloading joints".

Any contractor with experience in rock excavation should be aware that jointing near the surface of rock faces will likely be more predominant than at depth and that the shallow rock permeability will usually also be greater than at depth. The existence of flow from drill holes in the plug area should have been of no surprise and grouting, called for in the contract, was to be expected.

Section 5 of Section F - Lake Tap procedures states - "The quality of bedrock is good with average seismic velocities of 15,500 ft/sec. No weakness zones have been located in the immediate vicinity of the proposed lake tap location. (I interpret weakness zones to be major fault or shear zones.)

- Although no weakness zones or faults have been identified in the proposed lake tap location, it is generally the experience in performing lake taps that there will in fact be small open fissures, which may give rise to leaks during the final tunnelling operations. Probe drilling will reveal such aquiferous fissures, and it may be necessary to deviate somewhat from the planned

alignment for the lake tap plug in order to avoid these aquiferous fissures, if indeed they occur. Grouting of such aquifers may also be necessary.

- Actual angles of cracks in conjunction with the stratification of the rock may, during the blasting operations, give rise to the loosening of large blocks or flakes. Such conditions can also be detected ahead of time during probe drilling.

- In exceptional circumstances such conditions may necessitate corrections to the planned alignment; alternatively, it may be necessary to perform anchor-bolting from the tunnel side as a safeguard against failure of the rock in questionable sections.

- It is therefore important for a successful lake tap that probe drilling of meticulously monitored and accurate records thereof kept.

- Horizontal and vertical angles and distance to detectable cracks or fissures must be recorded and plotted onto drawings, and the drill log must contain all such necessary information. Logs will be available for Contractor's officer review. Original records will be submitted.

- The Contractor has a special responsibility in the period from the time probe drilling commences to the time the lake tap plug has been reached and its conformation established".

I conclude from the contract documents that joints are to be expected in the lake tap zone and grouting should be anticipated.

(c) <u>Accurate determination of rock quality and surface configuration</u>

Without detailed drilling at this location prior to construction the actual joint patterns and conditions were not accurately known. It was the intent of the contract to determine the rock conditions and potential need for grouting by drilling lake tap probe holes as the tunnel approached the plug zone.

Based on my review of the probe hole plan and logs I conclude that the Contractor performed the program as called for in the contract. As a result of the conditions encountered it was determined jointly by the Contractor's specialist and the Corps specialist that the alignment should be changed near the plug and that grouting was required.

In my opinion all parties acted responsibly and within the terms, intent and interpretation of the contract for the development of tunneling near the plug.

(d) Pilot and Probe Hole Claim

There was change in direction of some pilot and probe holes and the number of pilot and probe holes. The contract is based on unit prices. The correct payment to the Contractor simply involves the total footage times the unit rate bid per foot. If the total footage of pilot and probe holes exceeds the contract estimate he is entitled to an allowance of extra time for the contract.

The lake tap probe and pilot holes logs were provided to me (Appendix E). These were drilled between January 27 and February 12 and appear to exceed the contract footage. I suggest that an extention of time for this portion of the contract be prorated on the basis of the average footage drilled per day. I do not consider payment beyond the total footage times the unit rate to be justified.

no ? arb.

(e) Grout Claim

I was advised that the size of some joints or other openings in the rock required a change in grout materials and techniques from those called for in the contract. The Contractor's letter states that extra time was required for the grouting due to the changes.

It is my opinion the Contractor is entitled to be paid a deferential extra payment based on the extra cost of the changed grout materials compared to cement grout and for extra time required to prepare and pump the modified grout. I recommend the Contractor be requested to document costs and submit them to the Corps for consideration.

(f) Change of Alignemnt

The Contractor has submitted advice that he intends to claim because of extra time and costs due to a change in tunnel alignment near the Lake tap plug.

The contract is very clear regarding change of alignment.

Section 5 - General Lake Tap Discussions states "Probe drilling will reveal such acquiferous fissures, and it may be necessary to deviate somewhat from the alignment for the lake tap plug in order to avoid these aquiferous fissures, if indeed they occur. Grouting of such aquifers may also be necessary."

"In many cases the best and cheapest way of avoiding the consequences of driving through aquiferous weakness zones may be to change the direction of the tunnel and the lake tap location somewhat."

The contract specifies tunnel rock excavation be paid by the lineal foot. Changing the alignment would change the lineal footage and the payment accordingly. I consider payment based on the contract unit price to be fair compensation for the Contractor.

It is my understanding that the alignment change was made to improve the breakout alignment relative to the face and to reduce the estimated need for grouting.

In my opinion the change in alignment has not increased the difficulty to the Contractor but rather reduced the difficulty and increased the safety.

I recommend this claim be rejected.

4.0 Conclusions

The Contractor, Pacific Ventures Inc., has submitted notice of intent to the U.S. Corp of Engineers to claim re several issues on the Second stage development of the Crater Lake Snettisham Project. Based on my review of documentation, contracts, a site inspection and discussion with Corps representatives I have reached the following conclusions.

Hilltop Shear Zone

1. The Contractor did not meet the contract requirements to apply shotcrete for support when first requested by the Corps.

2. The rock conditions through the Hilltop shear zone were not as severe as the contract documents present.

3. The Contractor used excessive explosives blasting through the Hilltop shear zone. This required extra support.

4. The contract reasonably represents the conditions in the Hilltop shear.

Based on points 1, 2, 3 and 4 I recommend the Contractor's claim for changed conditions be rejected. In addition I consider the Contractor operated in a manner that increased the time required and the cost to the Corps through the shear zone such that a counter-claim can be justified.

Lake Top Area

1. The contract provided notice that joints could be expected near the lake tap plug.

2. The contract noted that grouting and change of tunnel alignment might be required as evaluated from the probe holes required under the contract.

3. The contract stated that probe and pilot hole loctions may be changed.

4. The pilot and probe hole program specified in the contract adequately determined the presence of joints and the plug face - lake configuration. By mutual agreement of the Contractor's specialist and Corps specialist, grouting was performed and the alignment was changed to improve conditions.

5. The grout requirements in the contract were changed and different materials were used.

It is my opinion that the Contractor's claim for change of hole locations, and change of tunnel alignment be rejected and that he be paid at contract unit prices for the quantities performed.

The grout materials were changed. I consider the Contractor has a legitimate claim for differential costs which exceed the cost of grouting with cement. I recommend the Contractor submit his extra costs for consideration.

C.O. Brawner, P. Eng.

COB/pm

ORIARD REPORT

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July 17, 1987
Rec'd 10/28/87

Attn: Mr. Ralph R. Mason

**SUBJECT: CRATER LAKE MAIN CONTRACT
SNETISHAM PROJECT, ALASKA
CONTRACT NO. DACW85-86-C-0019
DIFFERING SITE CONDITIONS.**

Gentlemen:

In accord with your request, I have traveled to your Bellevue, WA offices on 27 Spr 87, to discuss the Snettisham Project with you. We traveled on to Juneau on the evening of 27 Apr 87, and to the site of your construction operations on the morning of 28 Apr 87. I toured the construction site and examined drill cores. I returned to Juneau that night, and to California on 29 Apr 87.

In addition, I have now reviewed pertinent sections of the project plans, drawings and specifications, correspondence, diaries, records and cost estimates.

THE PROBLEM.

Several problems were encountered which had not been expected and which increased the time and cost of completing the work beyond those anticipated at the time of bidding. These included additional probe/pilot holes, excessive water, problems with the grouting, changes in the tunnel, changes in the secondary rock trap, and changes in the final lake plug and lake tap.

GENERAL COMMENT.

Geological information was provided to bidders in the customary format of boring logs. The cores themselves were also available for inspection. Bidders were also permitted a site visit, but it is my understanding that site access was limited. Only a few hundred feet of tunnel section was offered to view, and this limitation was misleading.

Another source of geological information is the "Crater Lake Phase I, Foundation Report", available through the Alaska District of the Corps of Engineers.

On some projects, bidders are unable to learn the Owner's opinion of the rock conditions, and have only factual information without judgment on which to base their own conclusions. In the present case, it is quite evident to bidders reading the contract documents what conditions were expected by the Owner. This is confirmed not only by conclusionary comments concerning the rock conditions, but also by the detailed design information and instructions provided to bidders. Bidders were given the shape, alignment and grade of rock excavation, including the detailed design of the rock traps, dimensions and number of rounds, location, length and direction of probe/pilot holes, description of the conditions to be encountered, grouting methods and materials, location and shape of the lake plug, and detailed instructions for the final tap round. This circumstance gave bidders a clear indication of the conditions to expect and the manner in which to perform the work, thus making bid preparation a routine task.

It appears to me to be clear that both the Government and the Contractor were expecting good rock. In some instances, the encountering of lower quality rock led immediately to additional cost, such as the case of excess water and problems with grouting. In other cases, your time and cost were increased by the Government's response to rock conditions which it did not consider satisfactory, and which led to a redesign/relocation of

some features of the work. After a study of the contract documents, it appears to me that the relocation/redesign of a rock trap, tunnel or lake tap is prima facie evidence either that the conditions were different than those anticipated by the Government at the time of bidding, and which could reasonably be anticipated by a prudent, experienced bidder, or that the Government changed the contract for other reasons not known to the Contractcor.

It is my conclusion that a prudent experienced bidder could not reasonably have expected the conditions and/or contract changes contributing to the extra time and cost claimed.

GEOLOGY.

For an overall description of the site and project, I found it useful to refer to the report titled "Snettisham Project Alaska, Second Stage Development, Crater Lake Phase I, Foundation Report, 1986". The report was prepared by Lachel Hansen & Associates, Inc., Golden, Colorado, as subcontractor to Polarconsult Alaska, Inc., Anchorage.

> "The Snettisham Hydroelectric Project is being constructed by the Alaska District of the U. S. Army Corps of Engineers. The project, located 28 air miles southwest of Juneau (Ed. The location map shows it to be southeast.) . . . . is operated by the U.S. Department of Energy, Alaska Power Administration . ."
>
> "The Snettisham Project is located at the head of the Snettisham fjord, near the mouth of the Speel River."
>
> "The second stage of the Snettisham Project encompasses the development of Crater Lake. Phase I of this project included the construction of a series of tunnels from the existing powerhouse to the vicinity of Crater Lake . . ."

A contract was awarded to South Coast, Inc. of Ketchikan for for 6772 ft. of 11-ft. tunnel, essentially unlined, enlarging the penstock, excavating a surge tank adit and a new powerhouse machine shop and its adit. Phase I of the work was completed on 28 October 1985.

Exploratory core drilling provided a total of 8,175.4 lineal feet, designed to investigate specific geologic features.

The rock consists predominantly of quartz diorite gneiss. Basalt and granite dikes were noted, as were shear zones. Several thick zones with a predominance of biotite and hornblende minerals were encountered in the tunnels. Drilling was faster in these zones. Some stress relief slabbing was observed in these zones.

Most of the discontinuities are joints, typically planar, relatively smooth and tight. Shears are the second most common discontinuity. There was very little effect on the rock outside the immediate shear zones.

SPECIFICATIONS.

The specifications provide information about the work to be done, how it is to be done, and the expected conditions.

Section 2F - LAKE TAP PROCEDURES.

1. SCOPE.

"The work covered by this section consists of furnishing all plant, labor, equipment and material necessary to:

(a) Perform, operate, maintain and control the Crater Lake deep underwater lake tap into the power tunnel."

Bidders would understand that they will have the responsibility to use due care and diligence in performing the work. But, when this information is combined with other sections of the specifications, bidders would recognize that they will not be designing the work. The Government has even designed certain features of work execution which are often left to the discretion of bidders, such as the exploratory drilling, blast round dimensions, plug dimensions, and plug blasting methods. The specifications make it clear to bidders that it is highly

unlikely that they would receive approval of any design that they might prefer to the Government's design. Thus, for many aspects of the work, the approval process would be conducted in such a way as to constitute direction of the work.

The specifications are well designed to meet the Government's needs. They provide bidders with detailed descriptions of the conditions and work to be performed, thus permitting well-defined, competitive bidding to meet those needs. Bidders need not add contingencies for unknowns because the Government's desires are well defined, and the bidders are protected by differing site conditions provisions.

5. GENERAL LAKE TAP DISCUSSION.

To assist the Contractor in planning his work to execute the Government's designs, and preparing his bid, some very helpful information is provided. The information/comment is generally very optimistic and would have the overall effect of inducing low bids. Bidders are advised:

1. There is no known underwater overburden to endanger the successful completion of the lake tap.

2. No overburden cleaning will be required.

3. **The quality of bed rock is good. No weakness zones have been located in the immediate vicinity of the proposed lake tap location.**

4. There is a general experience in work of this type that small, open fissures may be found which may give rise to leaks. It may be necessary to deviate from the plan, if indeed fissures are found. Grouting may also be necessary.

Additional comments are offered to bidders which advise them of the procedures which will be followed if the expected conditions are encountered, and what may be required if unexpected conditions are encountered.

Such comments are very helpful to bidders and the authors should be complimented for preparing them. For the purpose of

conveying the Government's design concepts, preferences for procedures, and general concerns, the comments are generally very informative to the bidders and to those who might be considered as possible lake tap consultants. However, these comments should not be construed as removing the Government's responsibility for differing site conditions. Bidders would conclude that the Government's responsibility cannot be removed merely by advising bidders of some of the possible alternative actions which may be required if a differing site condition is encountered. Bidders would conclude that it merely reduces the overall impact on the Government's costs if the Contractor can respond faster to the differing site condition. That may be beneficial to the project, but it would not be a basis for bidders to place contingencies in their bids for such various possible conditions.

6. PROBE DRILLING.

A very specific, detailed design of probe and pilot drilling is provided to bidders, although, quite appropriately, the Owner reserves the right to require additional or alternate drilling if conditions should so demand, that is if the conditions are different than expected.

Bidders are advised that the first pilot drilling shall take place from Sta 7+25. A hole shall be drilled 30 degrees above the tunnel axis. It shall extend approximately 65 ft. to the lake bottom and continue at least 5 ft. into the water.

The next pilot drilling shall begin at Sta 7+14. The hole shall be similar to that described above but shall be drilled at 15 degrees above the tunnel axis. Simultaneously, 20-ft. probes shall commence, as shown on the drawings. Probes shall be drilled for each round, one in each corner at 30 degree horizontal angles right and left, and at a 30 degree vertical angle with the tunnel axis.

Additional holes shall be drilled horizontally and below the

tunnel floor from the upstream edge of the primary rock trap. Positions and directions are specified.

Specified positions and directions are given, also, for probes when the last round is reached before the plug. Four probes shall be drilled, one in each corner of the face at 25 degree angles vertical and horizontal relative to the centerline of the plug. These shall extend 5-6 ft. into free water.

At the plug face itself, 5 probes shall be drilled 5-6 ft. into free water, one hole in each corner of the face at 15 degree angles vertical and horizontal, and one in the center of the plug.

Even the blasting rounds are numbered and dimensioned.

There seems to be some ambiguity in reference to "pilot" holes and "probe" holes. It may not be necessary to resolve the difference for the purposes of resolving the present problems. However, it appears that there are two aspects of the question that need resolution. One of these relates to the footage drilled. The other relates to the type of drilling done, whether by coring or by plug bits.

The specifications provided highly detailed instructions on how much drilling would be done. The Government could expect the lowest possible bids. It could expect bidders to prepare their bids with no need for contingencies when such detailed instructions are given. The Government confirms the detailed instructions for the amount of drilling when it provides a separate estimate of drill footage. The bidders would use this estimate and expect it to be more of a firm figure than normal. It was clear that the Government thought it knew the conditions very accurately, including the attitude and condition of the slope at the lake tap. However, this expectation was not realized. It happened that the estimate was greatly in error. Such drilling was approximately doubled. Bidders could not

reasonably have expected such an error in the estimate.

The second item deals with the matter of core drilling or drilling with plug bits. A prudent, experienced bidder will prepare his bid with the expectation of using the less costly of two choices, and a prudent, experienced Owner will know that bidders will do so. If an Owner seriously wants bidders to select the more costly alternative, they should be tolds that. The specifications will have to be re-written to make that clear. It is an easy matter for a specification writer to remove the ambiguity through text, quantity estimates and bid schedules. In the present case, this was not done. The Contractor could not reasonably have expected either the quantity of work demanded or the demand to use core drilling in preference to plug bits.

"When special conditions so demand, the Corps of Engineers may require additional probes, over and above those planned."

Bidders would understand readily that the Corps has specified precisely what will be done and reserves the right to change the specifications "when special conditions so demand" (changed conditions). The contractor would expect to conduct this portion of the work as directed/approved by the Government. (An experienced bidder knows that he must submit the design suggested by the Government or it will not be approved).

Exculpatory phrases in the specifications infer that the Government may try to transfer many of its designs and controls to the responsibility of the contractor. Bidders would still expect to be covered by differing site conditions and contract change protections. Bidders are aware that such exculpatory phrases do not remove the Government's responsibilities. Therefore, bidders could be expected to offer the lowest reasonable, prudent bids without contingencies for the problems under discussion here.

7. DRILLING, CHARGING AND FIRING OF THE LAKE TAP ROUND.

The Government specifies that the plug will be 12 ft., and that the drilled blast holes will be 10 ft. 6 in. The Government plan consists of a double burn cut with 11 blind holes of 3 in. diameter, 56 charged shotholes in and around the burn cut, and 19 charged shotholes in the plug perimeter.

The Government provides bidders with an example of explosives and cap selection (including the pounds of explosives and the cap delay numbers). Bidders would recognize that this blasting plan would be approved by the Government, and that any other plan would probably be rejected. In the event that a differing site condition should be encountered, bidders would recognize that some of the details might require adjustment, but that the same concept would be required.

WATER INFLOWS AND GROUTING.

Bidders are advised that they might encounter leaks of water. A reference is found in Sec. 7.2, page 2F-6:

> "If leaks of water occur in any of the shotholes, something which is quite common, rigid thinwalled plastic piping shall be inserted into the leaking shotholes. The plastic pipes shall be closed and sealed at the inner end and shall be held firmly in position by the use of thin slivers or wedges of dry wood. The water from the leaks will thus be drained between the outer surface of the plastic pipes and the inner surface of the shotholes."

Bidders would conclude from this specification that very little, if any, water is expected by the Government. The term "leak" implies a small quantity of water, as does the term "drained". If larger flows were expected, both the language and the method of handling it would have been quite different. Bidders would not expect problems with water inflows, nor with the grouting that would be associated with water.

Under the discussion of probe drilling, we see the statement, "The probe holes which need sealing should be plugged with slightly conical wooden plugs." Since it is specified that

the last 9 probe holes shall be drilled into free water, it is clear to bidders that these 9 holes will require plugs. This requirement is no indication that water will be found within the rock mass. The wording offered to bidders would lead to the conclusion that any additional water would be unlikely.

The amount of water actually encountered could not reasonably be described as "water leaks". These were substantial inflows.

The additional grouting required, in terms of severity, technology, time and cost, was a result of the unexpected heavy inflows of water. The added time and cost are part of the same differing site condition.

9. LAKE TAP RESPONSIBILITY.

The Government has a justified concern about the success of work of this type. It requires careful planning and execution to ensure success. Quite appropriately, the Government has required the Contractor, through the contract documents, to retain a lake tap engineer and an assistant. The Contracting Officer will also have a lake tap specialist. "This person will be working with the Contractor's Senior lake tap Engineer" (Page 2F-2, par. 4). This approach ensures the Government that its design concepts will be properly understood and executed.

The specifications contain exculpatory statements in an effort to transfer the Government designs and concepts to the Contractor.

> "Notwithstanding any of the above, it shall be the Contractor's responsibility to perform a successful lake tap, complete. The data provided is for general information and it is the Contractor's responsibility to provide his plan, which is subject to approval by the Contracting Officer. . . ."

Prudent, experienced bidders would recognize that the

Government cannot transfer its responsibilities to the Contractor in this fashion. However, the contract language is useful in making it clear to bidders what the Government has designed and that the Government is expecting bidders to perform the work carefully. Bidding would be routine because the bidders would not have to devise the technology already conceived and specified by the Government.

CHANGES IN ROCK TRAP, PLUG, LAKE TAP.

It appears to me that these design changes represent changes in the contract, whether or not they all represent differing site conditions. All of the reasons involved in the changes are known only to the Government. It is the Government's prerogative to make such changes whenever it chooses, within the confines of its obligations to the public good. Contractually, however, bidders would reasonably expect to be compensated when such changes result in added time and cost.

The Contractor did not see any direct problem in drilling, blasting and excavating the original design of these features. The extra time and cost came about because the Government relocated and/or redesigned these features.

The nature of lake taps is such that a modest change in final position and attitude would not be at all unusual. However, with the degree of information and direction provided to bidders in this case, it could be presumed that changes were unlikely and, if reqired by the Government, would be very modest changes having little impact on the time and cost of completing the work. The changes that were required here went far beyond anything that could reasonably have been anticipated.

Norma one

INVERT CONDITIONS.

Bidders were provided access to the site and permitted to walk through the first few hundred feet of the tunnel, as far upstream as the first tunnel juncture. The invert conditions

here appeared favorable for the efficient, rapid transport of rock rubble with rubber-tired equipment. Such was the appearance at the time of my visit, and there is reason to believe the appearance was even more favorable at the time of bidding because water flows would probably have been lower.

It would be reasonable for bidders to assume that the previous tunnel excavation would have been done in conventional fashion, in accord with standard practices in the industry, unless the bid documents or visual appearance would lead them to a different conclusion. Conventional work would leave a drainage trough or gutter at one side of the invert so that the tunnel contractor could use fines to maintain a relatively smooth road surface for his muck-handling equipment. Without the drainage trough, water flowing on the invert would wash away fines and leave a rough, irregular surface, adding a great deal to the time and cost of muck removal.

In providing information to bidders, the Government had an obligation to reveal that the invert was in an abnormal condition, knowing what impact this information would have on the future work coming up for bid.

It appears to me that the Contractor could not reasonably have expected this invert condition.

CONCLUSION.

It is my opinion that the Government has the prerogative to make changes/additions to the contracted work to meet its obligations to the public needs. However, it appears to me that prudent experienced bidders for this project could not reasonably have been expected to foresee the conditions actually encountered on this project nor the precise manner in which the Government would respond to those conditions. If bidders had placed sufficient contingencies in their bids at the time of the bidding to cover the extra time and cost of the unexpected work under discussion, it would not have been responsive to the bid

documents, nor to the Government's contracting practices. It is my conclusion that the Contractor's claim for additional compensation is justified.

Respectfully submitted:

LEWIS L. ORIARD, INC.

L. L. Oriard

Lewis L. Oriard